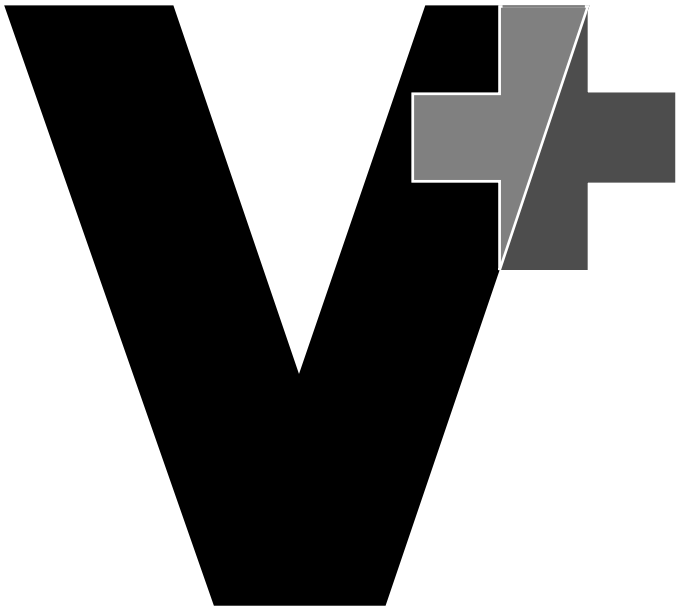
V+ Language

User's Guide

Version 11.0



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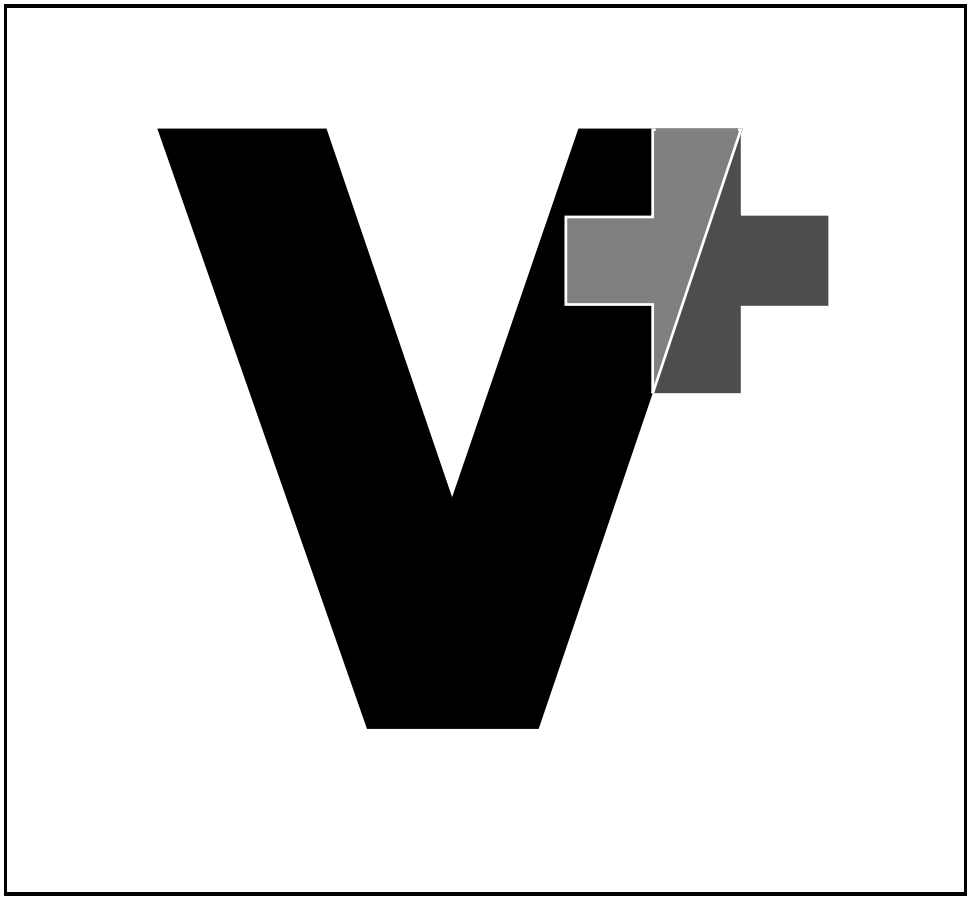

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adept technology, inc.

150 Rose Orchard Way • San Jose, CA 95134 • USA • Phone (408) 432-0888 • Fax (408) 432-8707
Otto-Hahn-Strasse 23 • 44227 Dortmund • Germany • Phone 0231/75 89 40 • Fax 0231/75 89 450
11, Voie la Cardon • 91126 • Palaiseau • France • Phone (1) 69.19.16.16 • Fax (1) 69.32.04.62
1-2, Aza Nakahara, Mitsuya-Cho • Toyohashi, Aichi-Ken • 441-31 • Japan • (0532) 65-2391 • Fax (0532) 65-2390

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V+ is a computer-based control system and programming language designed specifically for use with Adept Technology industrial robots, vision systems, and motion-control systems.

As a real-time system, continuous trajectory computation by V+ permits complex motions to be executed quickly, with efficient use of system memory and reduction in overall system complexity. The V+ system continuously generates robot-control commands and can concurrently interact with an operator, permitting on-line program generation and modification.

V+ provides all the functionality of modern high-level programming languages, including:

- Callable subroutines
- Control structures
- Multitasking environment
- Recursive, reentrant program execution

Compatibility

This manual is for used with V+ version 11.0 and later. This manual covers the basic V+ system. If your system is equipped with optional AdeptVision VME, see the *AdeptVision Reference Guide* and the *AdeptVision VME User's Guide* for details on the vision enhancements to basic V+ .

Manual Overview

The *V+ Language User's Guide* details the concepts and strategies of programming in V+. Material covered includes:

- Functional overview of V+
- A description of the data types used in V+
- A description of the system parameters and switches
- Basic programming of V+ systems
- Editing and debugging V+ programs
- Communication with peripheral devices
- Communication with the manual control pendant
- Conveyor tracking feature
- Example programs
- Using tool transformations
- Requirements for the system terminal
- Accessing external encoders

Many V+ keywords are shown in abbreviated form in this user guide. See the *V+ Language Reference Guide* for complete details on all V+ keywords.

Related Publications

In addition to this manual, have the following publications handy as you set up and program your Adept automation system:

Manual	Material Covered
Release Notes for V+ Version 11.0	Late-breaking changes not in manuals, Summary of Changes, Upgrading Pre-11.0 Code.
V+ Language Reference Guide	A complete description of the keywords used in the basic V+ system
V+ Operating System User's Guide	A description of the V+ operating system. Loading, storing, and executing programs is covered in this manual.
V+ Operating System Reference Guide	Descriptions of the V+ operating system commands (known as monitor commands).
AdeptVision VME User's Guide	Concepts and strategies for programming the AdeptVision VME system.
AdeptVision Reference Guide	The keywords available with systems that include the optional AdeptVision VME system.
Instructions for Adept Utility Programs	Adept provides a series of programs for configuring and calibrating various features of your Adept system. The use of these utility programs is described in this manual.
Adept MV Controller User's Guide	This manual details the installation, configuration, and maintenance of your Adept controller. The controller must be set up and configured before control programs will executed properly.
AdeptMotion VME User's Guide	Installation, configuration, and tuning of an AdeptMotion VME system.
Manual Control Pendant User's Guide	Basic use and programming of the manual control pendant.
AdeptForce VME User's Guide	Installation, operation, and programming of the AdeptForce VME product.
Robot or motion device user's guide	If your system is equipped with a robot or motion device, have the device's user guide handy.

Notes, Cautions, and Warnings

There are three levels of special notation used in this equipment manual. In descending order of importance, they are:

WARNING: If the actions indicated in a WARNING are not complied with, injury or major equipment damage could result. A WARNING will typically describe the potential hazard, its possible effect, and the measures that must be taken to reduce the hazard.

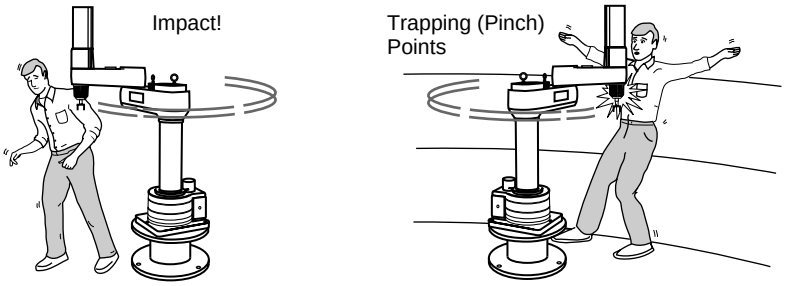
CAUTION: If the action specified in the CAUTION is not complied with, damage to your equipment could result.

NOTE: A NOTE provides supplementary information, emphasizes a point or procedure, or gives a tip for easier operation.

Safety

Reading and Training for System Users

Adept robot systems include computer-controlled mechanisms that are capable of moving at high speeds and exerting considerable force. Like all robot systems and industrial equipment, they must be treated with respect by the system user.



Impacts and Trapping Points

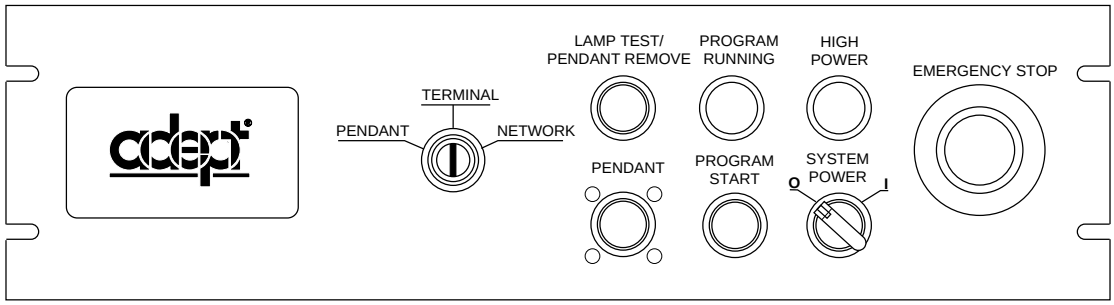
We recommend you read the *American National Standard for Industrial Robot Systems–Safety Requirements,* published by the Robotic Industries Association in conjunction with the American National Standards Institute. The publication, ANSI/RIA R15.06-1986, contains guidelines for robot system installation, safeguarding, maintenance, testing, startup, and operator training. The document is available from the American National Standards Institute, 1430 Broadway, New York, NY 10018.

System Safeguards

Safeguards should be an integral part of robot workcell design, installation, operator training, and operating procedures. Adept robot systems have various communication features to aid you in constructing system safeguards. These include remote emergency stop circuitry, and digital input and output lines.

Computer-Controlled Robots

Adept robots are computer controlled, and the program that is running the robot may cause it to move at times or along paths you may not anticipate. Your system should be equipped with indicator lights that tell operators when the system is active. The optional Adept front panel provides these lights. When the amber HIGH POWER light and the blue PROGRAM RUNNING light on the front panel are illuminated, do not enter the workcell because the robot may move unexpectedly.



High Power and Program Running Lights

Manually Controlled Robots

Adept robots can also be controlled manually when the amber HIGH POWER light on the front of the controller is illuminated. When this light is lit, robot motion can be initiated from the terminal or the manual control pendant. If you enter the workcell when this light is illuminated, press the MAN/HALT button on the manual control pendant. This will prevent anyone else from initiating unexpected robot motions from the terminal keyboard.

Other Computer-Controlled Devices

In addition, these systems can be programmed to control equipment or devices other than the robot. As with the robot, the program controlling these devices may cause them to operate at times not anticipated by personnel. Make sure that safeguards are in place to prevent personnel from entering the workcell when the blue PROGRAM RUNNING light on the front of the controller is illuminated.

WARNING: Entering the robot workcell when either the amber HIGH POWER or the blue PROGRAM RUNNING light is illuminated can result in severe injury.

Adept Technology recommends the use of additional safety features such as light curtains, safety gates, or safety floor mats to prevent entry to the workcell while HIGH POWER is enabled. These devices may be connected using the robot's remote emergency stop circuitry (see the controller user's guide).

Notations and Conventions

This section describes various notations used throughout this manual and conventions observed by the V+ system.

Keyboard Keys

The system keyboard is the primary input device for controlling the V+ system. Adept A-series systems use a "PC-style" keyboard and high-resolution graphics monitor. Adept S-series controllers use a Wyse WY-60, WY-70, or compatible terminal supplied by the user.

> **NOTE:** The word "terminal" is used throughout this manual to refer either to a computer terminal, or to the combination of a graphics monitor and a PC-style keyboard.

Input typed at the terminal must generally be terminated by pressing the **Enter** or **Return** key. (These keys are functionally identical and are often abbreviated with the symbol ↵.)

"S+F9" means to hold down the **Shift** key while the **F9** key is pressed.

"Ctrl+R" means to hold down the **Ctrl** key while the "R" key is pressed.

The keys in the row across the top of the keyboard are referred to as "function" keys. The V+ SEE program editor and the V+ program debugger use some of them for special functions.

> **NOTE:** The **Delete** and **BackSpace** keyboard keys can always be used to erase the last character typed. The Delete options associated with the F14 key on a Wyse terminal are used only by the SEE editor and the program debugger.

Uppercase and Lowercase Letters

You will notice that a mixture of uppercase (capital) and lowercase letters is used throughout this manual when V+ operations are presented. For clarity, all V+ keywords (for example, function and instruction names) are shown in uppercase, and all elements that can be freely specified by the user are shown in lowercase. That is the manner in which V+ displays material that has been previously entered (for example, when displaying a user program). However, you can enter material in either case that is convenient.

V+keywords are shown in uppercase letters. Parameters to keywords are shown in lowercase. Many V+ keywords have optional parameters and/or elements. Required keyword elements and parameters are shown in bold face type. Optional keyword elements and parameters are shown in normal type. If there is a comma following an optional parameter, the comma must be retained if the parameter is omitted, unless nothing follows. For example, the BASE operation (command or instruction) has the form

```
BASE dx, dy, dz, rotation
```

where all of the parameters are optional.

To specify only a 300-millimeter change in the Z direction, the operation could be entered in any of the following ways:

```
BASE 0,0,300,0
BASE,,300,
BASE,,300
```

Note that the commas preceding the number 300 must be present to correctly relate the number with a Z-direction change.

Numeric Arguments

All numbers in this manual are decimal unless otherwise noted. Binary numbers are shown as "^B", octal numbers as "^O", and hexadecimal numbers as "^H".

Several types of numeric arguments can appear in commands and instructions. For each type of argument, the value can generally be specified by a numeric constant, a variable name, or a mathematical expression.

There are some restrictions on the numeric values that are accepted by V+. The following rules determine how a value will be interpreted in the various situations described.

1. **Distances** are used to define locations to which the robot is to move. The unit of measure for distances is the millimeter, although units are never explicitly entered for any value. Values entered for distances can be positive or negative.[1]
2. **Angles** in degrees are entered to define and modify orientations the robot is to assume at named locations, and to describe angular positions of robot joints. Angle values can be positive or negative, with their magnitudes limited by 180 degrees or 360 degrees depending on the usage.
3. **Joint numbers** are integers from one up to the number of joints in the robot, including the hand if a servo-controlled hand is operational. For Adept SCARA robots, joint numbering starts with the rotation about the base, referred to as joint 1. For mechanisms controlled by AdeptMotion VME, see the device module documentation for joint numbering.
4. **Signal numbers** are used to identify digital (on/off) signals. They are always considered as integer values with magnitudes in the ranges 1 to 8, 33 to 232, 1001 to 1012, 1022 to 1236, or 2001 to 2512. A negative signal number indicates an "off" state.
5. **Integer** arguments can be satisfied with real values (that is, values with integer and fractional parts). When an integer is required, a real value may be used and the fractional part of the value is ignored.
6. Arguments indicated as being **scalar variables** can be satisfied with a real value (that is, one with integer and fractional parts) except where noted. Scalars can range from $-9.22*10^{18}$ to $9.22*10^{18}$ in value (displayed as –9.22E18 and 9.22E18).[2]

---

[1] See the IPS instruction for a special case of specifying robot speed in inches per second.

[2] Numbers specifically declared to be double-precision values can range from $2.2*10^{-308}$ to $18*10^{307}$.

Output Control Commands

The following special commands control output to the system terminal. For all these commands, which are called control characters, the control (**Ctrl**) key on the terminal is held down while a letter key is pressed. The letter key can be typed with or without the **Shift** key. Unlike other V+ commands, control characters do not need to be completed by pressing the **Enter** or **Return** key.

Ctrl+C	Aborts some commands (for example, DIRECTORY, LISTP, STORE). If any input has been entered at the keyboard since the current command was initiated, then the **first** Ctrl+C cancels that pending input and the **second** Ctrl+C aborts the current command. Ctrl+C cannot be used to abort program execution. Enter the ABORT or PANIC command at the keyboard to stop the robot program or press one of the panic buttons to turn off Robot Power.
Ctrl+S	Stops output to the monitor or terminal so it can be reviewed. The operation producing the output is stopped until output is resumed by Ctrl+Q.
Ctrl+Q	Resumes output to the monitor or terminal after it has been stopped with a Ctrl+S.
Ctrl+O	Suspends output to the monitor or terminal even though the current operation continues (that is, the output is lost). This is useful for disregarding a portion of a lengthy output. Another Ctrl+O will cause the output to be displayed again. The Ctrl+O condition will be canceled automatically when the current operation completes, or if there is an input request from an executing program.
Ctrl+W	Slows output to the monitor or terminal so it can be read more easily. A second Ctrl+W will terminate this mode and restore normal display speed. The Ctrl+W condition will be canceled automatically when the current operation completes, or if there is an input request from an executing program.
Ctrl+Z	If typed in response to a program prompt, terminates program execution with the message “*Unexpected end of file*.” This is sometimes useful for aborting a program. The following special control sequences are useful when entering information at the system keyboard.
Ctrl+R	Redisplays the current input line. This is useful when some output has occurred in the middle of an entry, making the line difficult to read.
Ctrl+U	Cancels the current input line. Useful if an error earlier in the line has been noticed or the current input line should be ignored for some other reason.

How Can I Get Help?

Within the Continental United States

Adept Technology maintains a Customer Service Center at its headquarters in San Jose, CA. The phone numbers are:

Service Calls

(800) 232-3378 (24 hours per day, 7 days a week)
(408) 433-9462 FAX

Application Questions

(800) 232-3378 (Monday to Friday, 8:00 a.m. to 5:00 p.m., Pacific time)
(408) 434-6248 FAX

Training Information

For information regarding Adept Training Courses in the USA, please call (408) 434-5024.

Within Europe

For European customers outside of France, Adept Technology maintains a Customer Service Center in Dortmund, Germany. The phone numbers are:

(49) 231 / 75 89 40 from within Europe (Monday to Friday, 8:00 a.m. to 5:00 p.m., CET)
(49) 231 / 75 89 450 FAX

France

For customers in France, Adept Technology maintains a Customer Service Center in Paris, France. The phone numbers are:

(33) 1 69 19 16 16 (Monday to Friday, 8:30 a.m. to 5:30 p.m., CET)
(33) 1 69 32 04 62 FAX

Outside Continental United States or Europe

For service calls, application questions, and training information, call the Adept customer service center in San Jose, California USA:

(408) 434-5000
(408) 433-9462 FAX (service requests)
(408) 434-6248 FAX (application questions)

> **NOTE:** When calling with a controller-related question, please have the serial number of the controller. If your system includes an Adept robot, also have the serial number of the robot. The serial numbers can be determined by using the ID command (see the *V+ Operating System User's Guide*).

Adept Bulletin Board Service

Adept maintains a bulletin board service for Adept customers. Adept posts application hints and utilities to this bulletin board and users may post their own hints and application notes. Other than long distance charges, there is no charge for access to the bulletin board. The BBS number is (203) 264-5590. The first time you call you will be able to set up an account right from the BBS. If you have any questions, call (800) 232-3378 and ask about the BBS.

1 Programming V+

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1.1 Creating a Program

V+ programs are created using the SEE editor. This section provides a brief overview of using the editor. Chapter 2 provides complete details on the SEE editor and program debugger. The editor is accessed from the system prompt with the command:

```
SEE prog_name
```

If `prog_name` is already resident in system memory, it will be opened for editing. If `prog_name` is not currently resident in system memory, the SEE editor will open and the bottom line will ask

```
"prog_name" doesn't exist. Create it? Y/N.
```

If you answer "Y", the program will be created, the SEE editor cursor will move to the top of the editing window, and you can begin editing the program. If you answer "N", you will be returned to the system prompt.

If `prog_name` is omitted, the last program edited will be brought into the editor for editing.[1]

Program and Variable Name Requirements

Program and variable names can have up to 15 characters. Names must begin with a letter and can be followed by any sequence of letters, numbers, periods, and underline characters. Letters used in program names can be entered in either lowercase or uppercase. V+ always displays program and variable names in lowercase.

The Editing Window

Adept S-series systems use a character-based terminal such as a Wyse WY-60. When the SEE editor is open, it will cover the entire terminal. Adept A-series systems use a graphicsbased keyboard and monitor. When the SEE editor is open, it will occupy the "Monitor" window on the monitor. If the "Monitor" window is not open, click on the **adept** logo in the upper left corner of the monitor and select "Monitor" from the displayed list.

Once the SEE editor is open, it functions nearly uniformly regardless of which type of Adept system it is used on. The primary functional difference between the SEE editor on the A- and S-series systems is the assignment of special key functions and the use of the pointing device. These differences are noted in the appropriate text.

See the *V+ Operating System User's Guide* for details on using the A-series monitor, keyboard, and pointing device. For S-series systems, see the documentation provided with your terminal.

Editing Modes

The SEE editor has three editing modes: command, insert, and replace. The status line shows the mode the editor is currently in (see Figure 1-1).

[1] Unless an executing program has failed to complete normally, in which case the failed program will be opened.

The editor begins in command mode. In command mode, you do not enter actual program code, but enter the special editor commands listed in Tables 2-3 and 2-4.

You enter actual lines of code in insert or replace mode. In insert mode, the characters you type are placed to the left of the cursor, and existing code is pushed to the right. In replace mode, the characters you enter replace the character that is under the cursor.

Changing Editing Modes

On A-series controllers, to enter command mode:
press the Edit (F11) key or Esc key

to enter insert mode:
- press the "Insert" key (the key's LED must be off)
- press the "0/Ins" key (the "Num Lock" LED must be off)
- press the "i" key (the editor must be in Command mode)

to enter replace mode:
- press the Replace (F12) key
- press the "r" key (the editor must be in Command mode)

On the Wyse terminal, press the F7 (EDIT) key to toggle between the three modes.

Using Text Editors Other Than the SEE Editor

Programs can be written using any editor that creates a "DOS ASCII text" file. These programs can then be stored on a V^+ compatible disk (see the FORMAT command), LOADed into system memory, and opened by the SEE editor. When the program is loaded, a syntax check is made and programs that fail the syntax check will be marked as non-executable. These programs can be brought into the SEE editor and any non-conforming lines will be marked with a question mark. Once these lines have been corrected, the program can be executed.

In order for program files created outside of the SEE editor to LOAD correctly the following requirements must be met:

- Each program must begin with a .PROGRAM() line.
- Each program must end with a .END line (this line is automatically added by the SEE editor but must be explicitly added by other editors).
- Each program line must be terminated with a carriage-return/line-feed (ASCII 13/ASCII10).
- The end of the file (not the end of each program) must be marked with a Control-Z character (ASCII 27).
- Lines that contain only a line-feed (AASCII10) are ignored.

The features of the SEE editor window are shown in Figure 1-1.

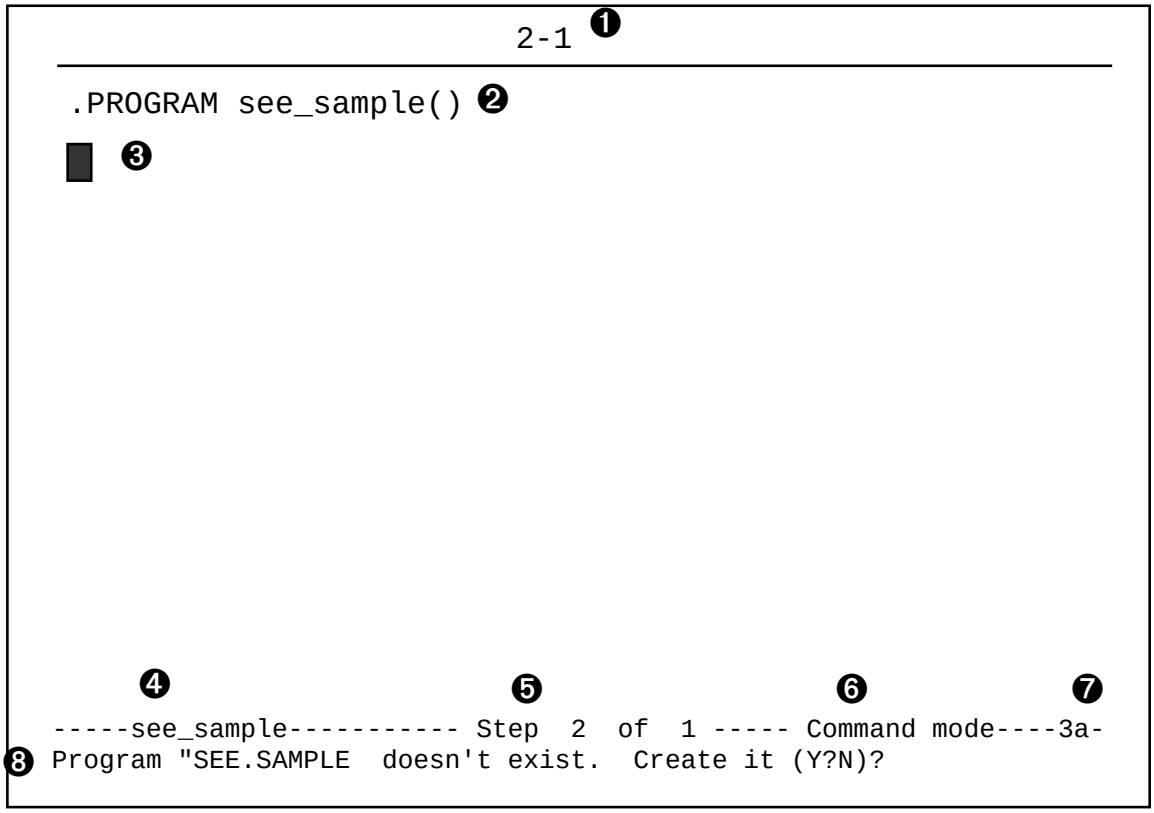

Figure 1-1. **The SEE Editor Window**

The SEE Editor Window

The items in the following numbered list refer to the numbers in Figure 1-1.

❶ On S-series terminals, this area shows the row and column of the cursor location.

❷ This line displays the program name and the program's parameter list. The program name cannot be edited, but program parameters can be added between the parentheses.

❸ The typing cursor:

In insert mode, characters entered at the keyboard will be entered at the cursor position. Existing characters to the right of the cursor will be pushed right.

In replace mode, the character under the cursor will be replaced.

In command mode, Copy, Paste, and similar commands will take place at the cursor location.

With an A-Series controller, clicking with the pointer device will set the typing cursor at the pointer location. (The cursor cannot be set lower than the last line in a program.) Also, the scroll bars on the monitor window can be used to scroll through the program.

❹ Shows the name of the program currently being edited. If the program is open in "read only" mode, "/R" will be appended to the name.[1]

❺ Shows the program step the cursor is at and the total number of lines in the program.

❻ Shows the current editor mode.

❼ Shows the number of lines in the copy (attach) buffer. Whenever a program line is Cut or Copied, it is placed in the copy buffer. When lines are pasted, they are removed from the copy buffer and pasted in the reverse order they were copied. The F9 and F10 keys are used for copying and pasting program lines.

❽ This is the message line. It displays various messages and prompts.

1.2 Using the Editor

Entering New Lines of Code

Once you have opened the editor and moved to insert or replace mode, you can begin entering lines of code. Each complete line of code needs to be terminated with a carriage return (↵). If a line of code exceeds the monitor line width, the editor will "wrap" the code to the next line and temporarily overwrite the next line. Do not enter a carriage return until you have typed the complete line of code.

When you press ↵ after completing a line of code, the SEE editor will automatically check the syntax of the line. Keywords are checked for proper spelling, instructions are checked for required arguments, parentheses are checked for proper closing, and in general the line is checked to make sure the V^+ system will be able to execute the line of code. (Remember, this check is solely for syntax, not for program logic.)

If the program line fails the syntax check, the system will place a question mark (?) at the beginning of the line (an usually display a message indicating the problem). You do not have to correct the line immediately, and you can exit the editor with uncorrected program lines. You will not, however, be able to execute the program.

Exiting the Editor

To complete an editing session and exit the editor, press the F13 key on a Wyse terminal or the Exit (F4) key on an A-series keyboard.

If your program is executable, you will be returned to the system prompt without any further messages.

If any lines of code in the program have failed the syntax check, the status line will display the message:

```
*Program not executable* Press RETURN to continue.
```

[1] Programs are open in "read-only" mode when "/R" is appended to the SEE command when the program is opened or when a currently executing program is open.

Pressing ↵ will return you to the system prompt.

You may also get the message:

```
*Control structure error at step xx*
```

This indicates that a control structure (described in Chapter 4) has not been properly ended. Pressing ↵ will return you to the system prompt, but the program you have been editing will not be executable.

You cannot exit the editor with lines in the copy buffer. To discard unwanted lines:

1. Put the editor in command mode.
2. Enter the number of lines to discard and press “Esc” and then “k”.

Saving a Program

When you exit the SEE editor, changes to the program you were working on are saved only in system memory. To permanently save a program to disk, use one of the STORE commands described in the *V+ Operating System User’s Guide*.

1.3 V+ Program Types

There are two types of V+ programs:

- Executable Programs
- Command Programs

Executable programs are described in this section. Command programs are similar to MS_DOS batch programs or UNIX scripts. They are described in the *V+ Operating System User’s Guide*.

Executable Programs

There are two classes of executable programs, robot control programs and general programs.

Robot Control Programs

A robot control program is a V+ program that directly controls a robot or motion device. It can contain any of the V+ program instructions.

Robot control programs are usually executed by program task #0, but they can be executed by any of the program tasks available in the V+ system. Task #0 automatically attaches the robot when program execution begins. If a robot control program is executed by a task other than #0, however, the program must explicitly attach the robot (program tasks are described in detail later in this chapter).

For normal execution of a robot control program, the system switch DRY.RUN must be disabled and the robot must be attached by the robot control program. Then, any robot-related error will stop execution of the program (unless an error-recovery program has been established [see “REACTE” on page 82]).[1]

Exclusive Control of a Robot

- Whenever a robot is attached by an active task, no other task can attach that robot or execute instructions that affect it (except for the BRAKE and REACTI instructions).
- When the robot control task stops execution for any reason, the robot is detached until the task resumes, at which time the task automatically attempts to reattach the robot. If another task has attached the robot in the meantime, the first task cannot be resumed.
- Task #0 always attempts to attach robot #1 when program execution begins. No other tasks can successfully attach any robot unless an explicit ATTACH instruction is executed.
- Since task #0 attempts to attach robot #1, that task cannot be executed **after** another task has attached that robot. If you want another task to control the robot **and** you want to execute task #0, you must follow this sequence of events:
  a. Start task #0.
  b. Have task #0 DETACH the robot.
  c. Start the task that will control the robot. (The program executing as task #0 can start up another task.)
  d. Have that task ATTACH the robot.
- Note that robots are attached even in DRY.RUN mode. In this case, motion commands issued by the task are ignored, and no other task can access the robot.

General Programs

A general program is any program that does not control a robot. With a robot system, there can be one or more programs executing concurrently with the robot control program. For example, an additional program might monitor and control external processes via the external digital signal lines and analog signal lines.

General programs can also communicate with the robot control program (and each other) through global variables and software signals. (General programs can also have a direct effect on the robot motion with the BRAKE instruction, although that practice is not recommended.)

With the exception of the BRAKE instruction, a general program cannot execute any instruction that affects the robot motion. Also, the BASE or TOOL settings cannot be changed by general programs.

Except for the robot, general-purpose control programs can access all the other features of the Adept system, including the AdeptVision option (if it is present in the system), the (internal and external) digital signal lines, the USER serial lines, the system terminal, the disk drives, and the manual control pendant.

---

[1] If the system is in DRY.RUN mode while a robot control program is executing, robot motion instructions are ignored. Also, if the robot is detached from the program, robot-related errors do not affect program execution.

Note that except for the exclusion of certain instructions, general-purpose control programs are just like robot control programs. Thus, the term “program” is used in the remainder of this chapter when the material applies to **either** type of control program.

1.4 Format of Programs

This section presents the format V+ programs must follow. The format of the individual lines is described, followed by the overall organization of programs. This information applies to all programs, regardless of their type or intended use.

Program Lines

Each line or **step** of a program is interpreted by the V+ system as a program instruction. The general format of a V+ program step is:

```
step_number step_label operation ;Comment
```

Each item is optional and is described in detail below.

Step Number — Each step within a program is automatically assigned a step number. Steps are numbered consecutively, and the numbers are automatically adjusted whenever steps are inserted or deleted. Although you will never enter step numbers into programs, you will see them displayed by the V+ system in several situations.

Step Label — Because step numbers change as a program evolves, they would not be useful for identifying steps for program-controlled branching. Therefore, program steps can contain a step label. A step label is a programmer-specified integer (0 to 65535) that is placed at the start of a program line to be referenced elsewhere in the program (used with GOTO statements).

Operation — The operation portion of each step must be a valid V+ language keyword and may contain parameters and additional keywords. The *V+ Language Reference Guide* gives detailed descriptions of all the keywords recognized by V+. Other instructions may be recognized if your system includes optional features, such as AdeptVision.

Comment — The semicolon character is used to indicate that the remainder of a program line is comment information to be ignored by V+.

When all the elements of a program step are omitted, a **blank line** results. Blank program lines are acceptable in V+ programs. Blank lines are often useful to space out program steps to make them easier to read.

When only the comment element of a program step is present, the step is called a **comment line**. Comments are useful to describe what the program does and how it interacts with other programs. Use comments to describe and explain the intent of the sections of the programs. Such internal documentation will make it easier to modify and debug programs.

The example programs in this manual, and the utility programs provided by Adept with your system, provide examples of programming format and style. Notice that Adept programs contain numerous comments and blank lines.

When program lines are entered, extra spaces can be entered between any elements in the line. The V+ editors add or delete spaces in program lines to make them conform with the standard spacing. The editors also automatically format the lines to uppercase for all keywords and lowercase for all user-defined names.

When you complete a program line (by entering a carriage return, moving off a line, or exiting the editor), the editor checks the syntax of the line. If the line cannot be executed, an error message is output.

Certain control structure errors are not checked until you exit from the editor (or change to editing a different program). If an error is detected at that time, an error message will be output and the program will be marked as not executable. (Error checking stops at that point in the program. Thus, only one control structure error at a time can be detected.)

Program Organization

The first step of every V+ program must be a ".PROGRAM" instruction. This instruction names the program, defines any arguments it will receive or return, and has the format:

```
.PROGRAM program_name(parameter_list)  ;Comment
```

The program name is required, but the parameter list and comment are optional.

After the .PROGRAM line, there are only two restrictions on the order of other instructions in a program.

- AUTO, LOCAL, or GLOBAL instructions must precede any executable program instructions. Only comment lines, blank lines, and other AUTO, LOCAL, or GLOBAL instructions are permitted between the .PROGRAM step and an AUTO, LOCAL, or GLOBAL instruction.
- The end of a program is marked by a line beginning with ".END". The V+ editors automatically add (but do not display) this line at the end of a program.[1]

Program Variables

V+ uses three classes of variables: GLOBAL, LOCAL, and AUTO. These are described in detail in section 3.6 on page 69.

[1] The ".PROGRAM" and ".END" lines are automatically entered by the V+ editors. If you use another text editor for transfer to a V+ system, you MUST enter these two lines. In general, any editor that produces unformatted ASCII files can be used for programming. See the FORMAT command for details on creating floppy disks compatible with other operating systems.

1.5 Executing Programs

When V+ is actively following the instructions in a program, it is said to be "executing" that program.

The standard V+ system provides for simultaneous execution of up to seven different programs—for example, a robot control program and up to six additional programs. The optional V+ extensions software provides for simultaneous execution of up to 28 programs. Execution of each program is administered as a separate "program task" by the system.

The way program execution is started depends upon the program task to be used, and the type of program to be executed. The following sections describe program execution in detail.

Selecting a Program Task

Task 0 has the highest priority in the (standard) task configuration. Thus, this task is normally used for the primary application program. For example, with a robot system, task #0 is normally used to execute the robot control program.

> **NOTE:** As a convenience, when execution of task #0 begins, the task always automatically selects robot #1 and attaches the robot.

Execution of task #0 is normally started by using the EXECUTE monitor command, or by priming the program from the manual control pendant and pressing the PROGRAM START button on the optional front panel. The RUN / HOLD button on the manual control pendant can be held down to execute portions of the program executing as task #0.

While task #0 is executing, the V+ monitor will not display its normal dot prompt. An asterisk ("*") prompt is used instead to remind the user that task #0 is executing. The asterisk prompt does not appear automatically, however. The prompt is displayed whenever there is input to the V+ system monitor from the system terminal.

> **NOTE:** Even though the system prompt is not displayed while program task #0 is executing, V+ monitor commands can be entered at any time that a program is not waiting for input from the terminal.

The ABORT monitor command or program instruction will stop task #0 after the current robot motion completes. The CYCLE.END monitor command or program instruction can be used to stop the program at the end of its current execution cycle.

If program execution stops because of an error, a PAUSE instruction, or an ABORT command or instruction, the monitor commands PROCEED or RETRY can be used to resume execution. While execution is stopped, the DO monitor command can be used to execute a single program instruction (entered from the keyboard) as though it were the next instruction in the program that is stopped.

For debugging purposes, the SSTEP or XSTEP monitor commands can be used to execute a program one step at a time. Also, the TRACE feature can be used to follow the flow of program execution. (The program debugger can also be used to execute a program one instruction at a time. See Chapter 2 for information on the V+ program debugger.)

Execution of program tasks other than #0 is generally the same as for task #0. The following points highlight the differences:

- The task number must be explicitly included in all the monitor commands and program instructions that affect program execution, including EXECUTE, ABORT, PROCEED, RETRY, SSTEP, and XSTEP. (However, when the V+ program debugger is being used, the task being accessed by the debugger becomes the default task for all these commands.)
- If the program is going to control the robot, it must explicitly ATTACH the robot before executing any instructions that control the robot.
- If task 0 is not executing concurrently, the V+ monitor prompt continues to be a dot (“.”). Also, the prompt **is** displayed after the task-initiating EXECUTE command is processed.

  NOTE: If you want program execution to be delayed briefly to allow time for the dot prompt to be output (for example, to prevent it from occurring during output from the program), have your program execute two WAIT instructions with no parameter.

- The TRACE feature does not apply to tasks other than #0.

  NOTE: To use TRACE with a program that is intended to execute in a task other than #0, execute the program as task #0. (This consideration does not apply when using the V+ program debugger, which can access any program task.)

See section 1.9 for details on task scheduling.

1.6 Program Stacks

When subroutine calls are made, V+ uses an internal storage area called a “stack” to save information required by the program that begins executing. This information includes:

- The name and step number of the calling program.
- Data necessary to access subroutine arguments.
- The values of any automatic variables specified in the called program.

The V+ system allows you to explicitly allocate storage to the stack for each program task. Thus, the amount of stack space can be “tuned” for a particular application to optimize the use of system memory. Stacks can be made arbitrarily large, limited only by the amount of memory available on your system.

Stack Requirements

When a V+ program is executed in a given task, each program stack is allocated six kilobytes of memory. This value can be adjusted, once the desired stack requirements are determined, by using the STACK monitor command (for example, in a start-up monitor command program).

One method of determining the stack requirements of a program task is simply to execute its program. If the program runs out of stack space, it will stop with the error message

```
*Too many subroutine calls*
```

or

```
*Not enough stack space*
```

If this happens, use the STACK monitor command to increase the stack size and then issue the RETRY monitor command to continue program execution. In this case, you do not need to restart the program from the beginning. (The STATUS command will tell you how much stack space a failed task requested.)

Alternatively, you can start by setting a large stack size before running your program. Then execute the program. After the program has been run, and all the execution paths have been followed, use the STATUS monitor command to look at the stack statistics for the program task. The stack "MAX" value shows how much stack space your program task needs to execute. The stack size can then be set to the maximum shown, with a little extra for safety.

If it is impossible to invoke all the possible execution paths, the theoretical stack limits can be calculated using Table 1-1. You can calculate the worst-case stack size by adding up the overhead for all the program calls that can be active at one time. Divide the total by 1024 to get the size in kilobytes. Use this number in the STACK monitor command to set the size.

Table 1-1. **Stack Space Required by a Subroutine**

Bytes	Required For	Notes
20	The actual subroutine call	
32	Each subroutine argument (plus one of the following):	
4	Each real subroutine argument or automatic variable	1
48	Each transformation subroutine argument or automatic variable	1, 2
varies	Each precision-point subroutine argument or automatic variable	1, 2, 3
84	Each belt variable argument or automatic variable	1, 2
132	Each string variable argument or automatic variable	1, 2

Notes:
1. If any subroutine argument or automatic variable is an array, the size shown must be multiplied by the size of the array. (Remember that array indexes start at zero.)
2. If a subroutine argument is always called by reference, this value can be omitted for that argument.
3. Requires four bytes for each joint of the robot (on multiple robot systems, use the robot with the most joints).

1.7 Flow of Program Execution

Program instructions are normally executed sequentially from the beginning of a program to its end. This sequential flow may be changed when a GOTO or IF...GOTO instruction, or a control structure, is encountered. The CALL instruction causes another program to be executed, but it does not change the sequential flow through the calling program since execution resumes where it left off when the CALLed program executes a RETURN instruction.

The WAIT instruction suspends execution of the current program until a condition is satisfied. The WAIT.EVENT instruction suspends execution of the current program until a specified event occurs or until a specified time elapses.

The PAUSE and HALT instructions both terminate execution of the current program. After a PAUSE, program execution can be resumed with a PROCEED monitor command. Execution cannot be resumed after a HALT.

The STOP instruction may or may not terminate program execution. If there are more program execution cycles to perform, the STOP instruction causes the **main** program to be restarted at its first step (even if the STOP instruction occurs in a subroutine). If no execution loops remain, STOP terminates the current program.

RUN/HOLD Button

Execution of program task #0 can also be controlled with the RUN / HOLD button on the manual control pendant. When a program is executing and the RUN / HOLD button on the pendant is pressed, program execution is suspended.

If the keyswitch on the optional front panel or on a remote front panel is set to "PENDANT", program execution will resume if the RUN / HOLD button is held down—but execution will stop again when the button is released. Normal program execution can be resumed by pressing the PROGRAM START button on the optional front panel (the system switch RETRY must be enabled)

If the keyswitch on the optional front panel or on a remote front panel is set to "TERMINAL", program execution can be resumed by entering a PROCEED or RETRY monitor command at the system terminal.

1.8 Subroutines

There are three methods of exchanging information between programs:

The first method is with global variables. Simply use the same variable names in the different programs. Unless used carefully, this method can make program execution unpredictable and hard to debug. It also makes it difficult to write generalized subroutines because the variable names in the main program and subroutine must always be the same.

The second method is with the internal program signals known as soft-signals. These are digital software switches whose state can be read and set by all tasks and programs

(including across CPUs in multiple CPU systems). See “Soft Signals” on page 145 for details.

The third method of exchanging information is through the program argument list. This method gives you better control of when variables are changed. It also eliminates the requirement that the variable names in the calling program be the same as the names in the subroutine. The following sections describe exchanging data through the program parameter list.

Argument Passing

There are two important considerations when passing an argument list from a calling program to a subroutine. The first is making sure the calling program passes arguments in the way the subroutine expects to receive them (mapping). The second is determining how you want the subroutine to be able to alter the variables (passing by value or reference).

Mapping the Argument List

An argument list is a list of variables or values separated by commas. The argument list passed to a calling program must match the subroutine’s argument list in number of arguments and data type of each argument (see “Undefined Arguments” on page 26). The variable names do not have to match. When a calling program passes an argument list to a subroutine, the subroutine does not look at the variable names in the list, but the position of the arguments in the list. The argument list in the CALL statement is mapped item for item to the argument list of the subroutine. It is this mapping feature that allows you to write generalized subroutines that can be called by any number of different programs, regardless of the actual values or variable names the calling program uses. Figure 1-2 shows the mapping of an argument list in a CALL statement to the argument list in a subroutine. The arrows indicate that each item in the list must match in position and data type but not necessarily in name. (The CALL statement argument list can include values and expressions as well as variable names.)

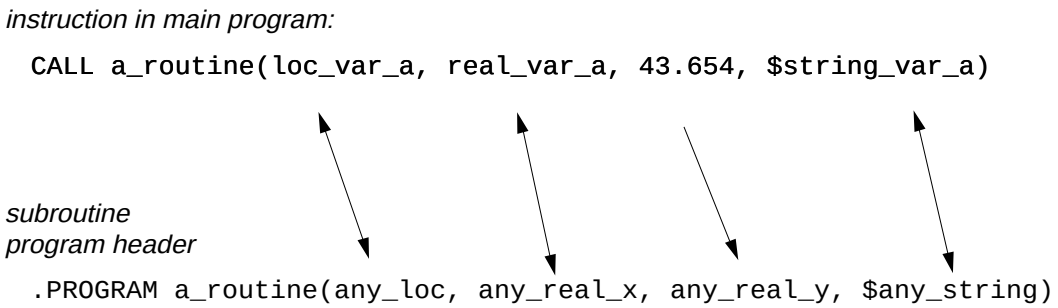

Figure 1-2. **Argument Mapping**

In the example in Figure 1-2, when the main program reaches the CALL instruction shown at the top of the figure, the subroutine “a_routine” is called and the argument list is passed as shown.

See the description of the CALL instruction for additional details on passing arrays.

Argument Passing by Value or Reference

An important principle to grasp in using subroutine calls is how the variables being passed are affected. Variables can be changed by a subroutine, and the changed value can be passed back to the calling program. If a calling program passes a variable to a subroutine, and the subroutine can change the variable and pass back the changed variable to the calling program, the variable is said to be "passed by reference." If a calling program passes a variable to a subroutine but the subroutine cannot pass back the variable in an altered form, the variable is said to be "passed by value."

Variables you want changed by a subroutine should be passed by reference. All the variables passed in the CALL statement in Figure 1-2 are being passed by reference. Changes made by the subroutine will be reflected in the state of the variables in the calling program. Arguments that are to be changed by a subroutine and passed back to the calling routine must be specified as a variable (not an expression or value).

In addition to passing variables whose value you want changed, you will also pass variables that are required for the subroutine to perform its task but whose value you do not want changed after the subroutine completes execution. Pass these variables by value. When a variable is passed by value, a copy of the variable, rather than the actual variable, is passed to the subroutine. The subroutine can make changes to the variable, but the changes are not returned to the calling program (the variable in the calling program will have the same value it had when the subroutine was called). Figure 1-3 shows how to pass the different types of variables by value. Reals and integers are surrounded by parentheses, ":NULL" is appended to location variables, and "+""" is appended to string variables (see Chapter 3 for details on the different variable types). In Figure 1-3, "real_var_b" is still being passed by reference, and any changes made in the subroutine will be reflected in the calling program. The subroutine cannot change any of the other variables, it can make changes only to the copies of those variables that have been passed to it. (It is considered poor programming practice for a subroutine to change any arguments except those that are being passed back to the calling routine. If in input argument must be changed, we suggest you make an AUTOmatic copy of the argument and work with the copy.)

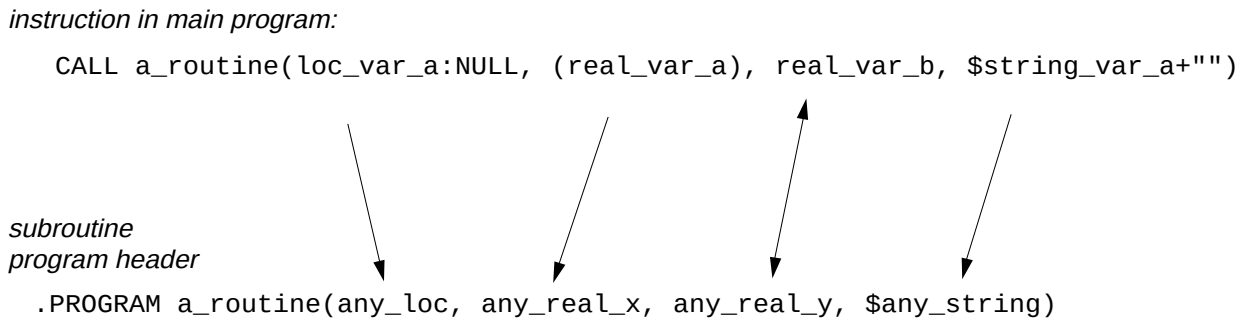

Figure 1-3. **Call by Value**

Values, as well as variables, can be passed by a CALL statement. The instruction:

```
CALL a_routine(loc_1, 17.5, 121, "some string")
```

would be an acceptable call to "a_routine".

Undefined Arguments

If the calling program omits an argument, either by leaving a blank in the argument list (e.g., “arg_1, , arg_3”) or by omitting arguments at the end of a list (e.g., “arg_1, arg_2”), the argument will be passed as “undefined”. The subroutine receiving the argument list can test for this value using the DEFINED function and take appropriate action.

Program Files

Since linking and compiling are not required by V+, main programs and subroutines always exist as separate programs. The V+ file structure allows you to keep a main program and all the subroutines it CALLs or EXECUTEs together in a single file so that when a main program is loaded, all the subroutines it calls are also loaded. (If a program calls a subroutine that is not resident in system memory, the error “*Undefined program or variable name*” will result.)

See the descriptions of the STORE_ commands and the MODULE command in the *V+ Operating System User’s Guide* for details. For an example of creating a program file, see section 2.2 on page 49.

Reentrant Programs

The V+ system allows the same program to be executed concurrently by multiple program tasks. That is, the program can be “reentered” while it is already executing.

This allows different tasks that are running concurrently to use the same general-purpose subroutine.

To make a program reentrant, you must observe a few general guidelines when writing the program:

- Global variables can be read, but must not be modified.
- Local variables should not be used.
- Only automatic variables and subroutine arguments can be modified.

In special situations, local variables can be used, and global variables can be modified, but then the program must explicitly provide program logic to interlock access to these variables. The TAS real-valued function may be helpful in these situations. (See the *V+ Language Reference Guide* for details.)

Recursive Programs

Recursive programs are subroutines that call themselves, either directly or indirectly. A direct call occurs when a program actually calls itself, which is useful for some special programming situations. Indirect calls are more common. They occur when program “A” calls program “B”, which eventually leads to another call to program “A” before program “B” returns. For example, an output routine may detect an error and call an error-handling routine, which in turn calls the original output routine to report the error.

If recursive subroutine calls are used, the program must observe the same guidelines as for reentrant programs (see above). In addition, you must guarantee that the recursive calls do not continue indefinitely. Otherwise, the program task will run out of stack space.

> **NOTE:** Very strange results may occur if a non-reentrant program is inadvertently called from different tasks (or recursively from a single task). Therefore, it is good practice to make programs reentrant if possible.

Asynchronous Processing

A particularly powerful feature of V+ is the ability to respond to an event (such as an external signal or error condition) when it occurs, without the programmer having to include instructions to test repeatedly for the event. If event handling is properly enabled, V+ will react to an event by invoking a specified program just as if a CALL instruction had been executed. Such a program is said to be called asynchronously, since its execution is not synchronized with the normal program flow.

Asynchronous processing is enabled by the REACT, REACTE, and REACTI program instructions. Each program task can use these instructions to prepare for independent processing of events. In addition, the optional V+ Extensions software uses the WINDOW instruction to enable asynchronous processing of window violations when the robot is tracking a conveyor belt (see Chapter 11).

Sometimes, a reaction must be delayed until a critical program section has completed. Also, since some events are more important than others, a program should be able to react to some events but not others. V+ allows the relative importance of a reaction to be specified by a program priority value from 1 to 127. The higher the program priority setting, the more important is the reaction.

> **NOTE:** Do not confuse "program priority" (described here) with "task priority" (described later in this chapter). Task priority governs the processing of the various system tasks. Program priority governs the execution of programs within a program task. See section 4.3 for further details; see Figure 4-1 for an example.

A reaction subroutine is called only if the main program priority is less than that of the reaction program priority. If the main program priority is greater than or equal to the reaction program priority, execution of the reaction subroutine is deferred until the main program priority drops. Since the main program (for example, the robot control program) normally runs at program priority zero and the minimum reaction program priority is one, any reaction can normally interrupt the main program.

The main program priority can be raised or lowered with the LOCK program instruction, and its current value can be determined with the PRIORITY real-valued function. When the main program priority is raised to a certain value, all reactions of equal or lower priority are locked out.

When a reaction subroutine is called, the main program priority is automatically set to the reaction program priority, thus preventing any reactions of equal or lower program priority from interrupting it. When a RETURN instruction is executed in the reaction program, the main program priority is automatically reset to the level it had before the reaction subroutine was called.

For further information on reactions and program priority, see the following keywords: LOCK, PRIORITY, REACT, and REACTI.

Error Trapping

Normally, when an error occurs during execution of a program, the program is terminated and an error message is displayed on the system terminal. However, if the REACTE instruction has been used to enable an error-trapping program, the V+ system will invoke that program as a subroutine instead of terminating the program that encountered the error. (Each program task can have its own error trap enabled.)

Before invoking the error-trapping subroutine, V+ locks out all other reactions by raising the main program priority to 254 (see above). See the description of the REACTE instruction for further information on error trapping.

1.9 Scheduling of Program Execution Tasks

The V+ system appears to execute all the program tasks at the same time. However, this is actually achieved by rapidly switching between the tasks many times each second, with each task receiving a fraction of the total time available. This is referred to as concurrent execution. The following sections describe how execution time is divided among the different tasks.

> **NOTE:** The default task configuration will work for most applications: You will not have to alter task execution priorities. The default configuration is optimized for Adept's AIM software.

System Timing and Time Slices

The amount of time a particular program task receives is determined by two parameters: its assignment to the various "time slices", and its "priority" within the time slice. A brief description of the system timing will help you to understand what a time slice is and how one can be selected.

> **NOTE:** Do not confuse "task priority" (described here) with "program priority" (described earlier in this chapter). Task priority governs the processing of the various system tasks within a time slice. Program priority governs the execution of programs within a task. See section 4.3 for further details; see Figure 4-1 for an example.

Each system cycle is divided into 16 time slices of one millisecond each. The time slices are numbered 0 through 15. A single occurrence of all 16 time slices is referred to as a "major cycle". For a robot or motion system, each of these cycles corresponds to one output from the V+ trajectory generator to the digital servos.

Specifying Tasks, Time Slices, and Priorities

Tasks 0 through 6 (0 through 27 with optional V+ Extensions software) can be used, and their configuration can be tailored to suit the needs of specific applications.

Each program task configured for use requires dedicated system memory, which is unavailable to user programs. Therefore, the number of tasks available should be made no larger than necessary, especially if memory space for user programs is critical.

When application programs are executed, their program tasks are normally assigned "default" time slices and priorities according to the current system configuration. These defaults can be overridden temporarily for any user program task. This is done by specifying the desired time-slice and priority parameters in the EXECUTE, PRIME, or XSTEP command used to initiate execution. The temporary values remain in effect until the program task is started again, by a new EXECUTE, PRIME, or XSTEP command. (See the *V+ Language Reference Guide* for details on these instructions.)

Task Scheduling

Tasks are scheduled to run with a specified priority in one or more time slices. Tasks may have priorities from –1 to 64, and the priorities may be different in each time slice. The priority meanings are:

–1 Do not run in this slice even if no other task is ready to run.

0 Do not run in this slice unless no task from this slice is ready to run.

1 - 64 Run in this slice according to specified priority. Higher priority tasks may lock out lower ones. Priorities are broken into the following ranges:

1 - 31 Normal user task priorities.

32-62 Used by V+ device drivers and system tasks.

63 Used by the trajectory generator. Do not use 63 or 64 unless you have very short task execution times. Use of these priorities may cause jerks in robot trajectories.

Whenever the current task becomes inactive (e.g., due to an I/O operation, a WAIT instruction, or completion of the task programs), V+ searches for a new task to run. The search begins with the highest priority task in the current time slice and proceeds through that slice in order of descending priority. If multiple programs are waiting to run in the task, they are run according to the relative program priorities. If a runnable task is not found, the next higher slice is checked. All time slices are checked, wrapping around from slice 15 to slice 0 until the original slice is reached. If no runnable tasks are encountered, the V+ null task executes.

Whenever a 1ms interval expires, V+ performs a similar search of the next time slice. If the next time slice does not contain a runnable task, the currently executing task continues.

If more than one task in the same time slice have the same priority, they become part of a round-robin scheduling group. Whenever a member of a round-robin group is selected by the normal slice searching, the group is scanned to find the member of the group that ran most recently. The member that follows the most recent is run instead of the one that was originally selected. If a task is in more than one round-robin group in different slices, then all such tasks in both slices appear to be in one big group. This property can cause a task to be run in a slice you did not expect. For example:

Slice 1: Task A priority 10, Task B priority 10

Slice 5: Task B priority 15, Task C priority 15

All three tasks, A, B, and C, are in the same round-robin group because task B appears in both. Therefore, task C may run in slice 1 at priority 10, or task A may run in slice 5 at priority 15, depending on which member of the group ran most recently.

The RELEASE program instruction may be used to bypass the normal scheduling process by explicitly passing control to another task. That task then gets to run in the current time slice until it is rescheduled by the 1ms clock. A task may also RELEASE to "anyone", which means that a normal scan is made of all other tasks to find one that is ready to run. During this scan, members of the original task's round-robin group (if any) are ignored. Therefore, RELEASE to "anyone" cannot be used to pass control to a different member of the current group.

A WAIT program instruction with no argument suspends a task until the start of the next major cycle (slice 0). At that time, the task becomes runnable and will execute if selected by the normal scheduling process. A WAIT with an expression performs a release to "anyone" if the expression is FALSE.

On systems that include the V+ extensions, the V+ task profiler can be used to determine how the various tasks are interacting. It provides a means of determining how much time is being used by each task either on an average basis, or as a "snapshot" of several consecutive cycles.

Within each time slice, the task with highest priority can be locked out only by a servo interrupt. Tasks with lower priority can run only if the higher-priority task is inactive or waiting. A user task waits whenever any of the following occurs:

- The program issues an input or output request that causes a wait.
- The program executes a robot motion instruction while the robot is still moving in response to a previous motion instruction.
- The program executes a WAIT or WAIT.EVENT program instruction.

If a program is executing continuously without performing any of the above operations, it will lock out any lower-priority tasks in its time slice. Thus, programs that execute in a continuous loop should generally execute a WAIT (or WAIT.EVENT) instruction occasionally (for example, once each time through the loop). This should not be done, of course, if timing considerations for the application preclude such execution delays.

If a program potentially has a lot of critical processing to perform, its task should be in multiple slices, and the task should have the highest priority in these slices. This will guarantee the task's getting all the time needed in the multiple slices, plus (if needed) additional unused time in the major cycle.

Figure 1-4 shows the task scheduler algorithm. This flow chart assumes that the servo task is configured to run every 1ms and no task issues a RELEASE instruction. (Actually, at the point marked "run servos?", any system level interrupts are processed—in motion systems the servo task is generally the most likely to interrupt and is the most time-consuming system task.)

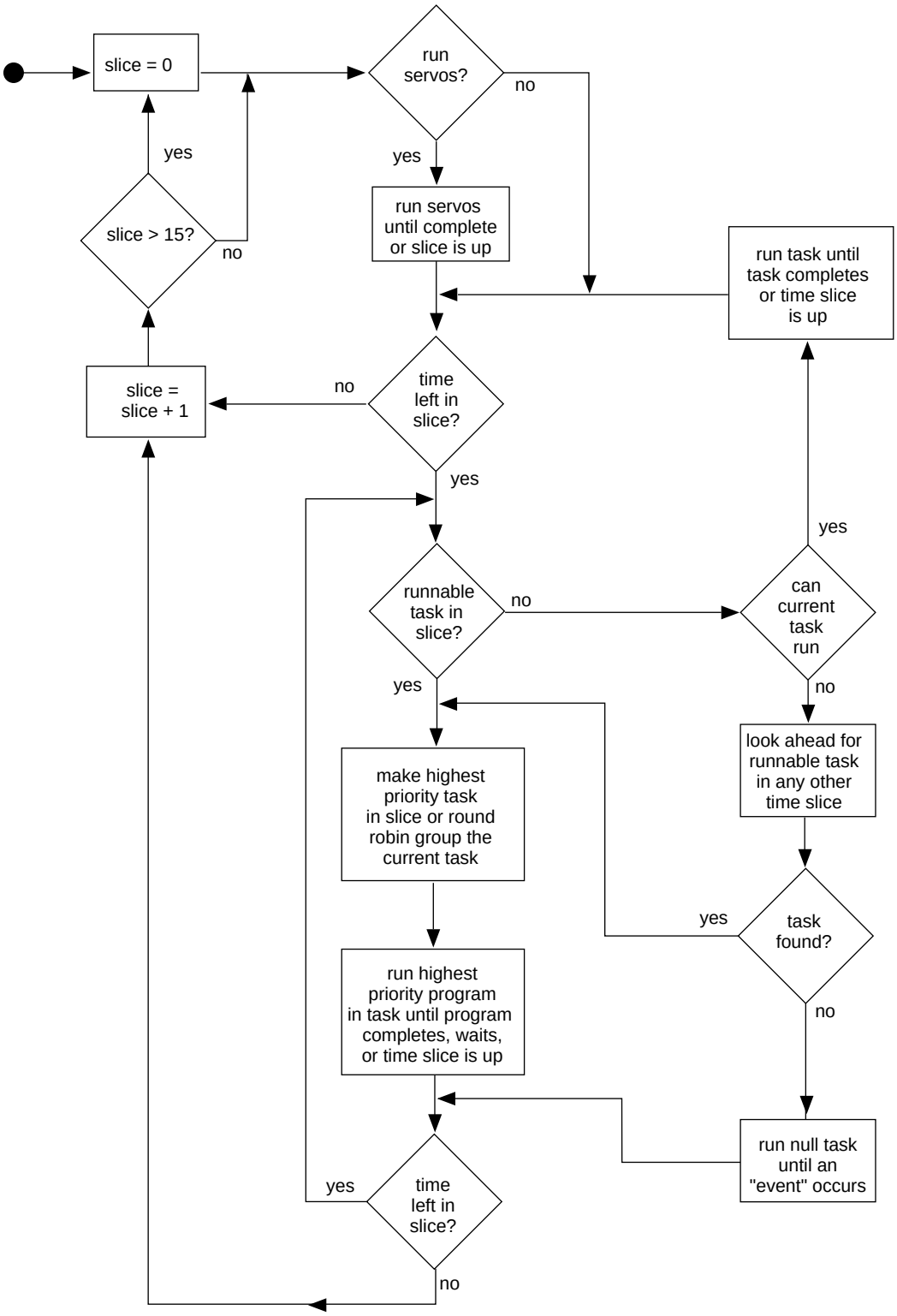

Figure 1-4. **Task Scheduler**

Execution Priority Example

The following example shows how the task priority scheme works. The example makes the following simplifying assumptions:

- Task 0 runs in all time slices at priority 20
- Task 1 runs in all time slices at priority 10
- Task 2 runs in all time slices at priority 20
- All system tasks are ignored (systems tasks are described in the next section)
- All system interrupts are ignored

Figure 1-5 shows three tasks executing concurrently. Note that since no LOCK or REACT_ instructions are issued, the program priority remains 0 for the entire segment. (See section 4.3 for descriptions of the REACT routines, the LOCK instruction, and another program execution example.)

The illustration shows the time lines of executing programs. A solid line indicates a program is running and a dotted line indicates a program is waiting. The Y axis shows the program priority. The X axis is divided into 1-millisecond time slices.

The sequence of events for Priority Example 1 is:

❶ "prog_a" issues a WAIT.EVENT. This suspends "prog_a" and passes execution to the next highest task which is task 2 running "prog_c".

❷ "prog_c" runs until it issues a RELEASE instruction. Since the RELEASE has no arguments, execution is passed to the next highest task with a program to run. Since task 0 is waiting on a SET.EVENT, the next task is task 1.

❸ Task 2 issues a SET.EVENT to task 0 and runs until the end of a time slice at which time task 0 runs. Tasks 0 and 2 have the same priority so they swap execution. (If two tasks with equal priority are ready to run, the least recently run task runs.)

❹ "prog_c" waits for a disk I/O operation to complete. The next highest priority task is 2 which runs until the I/O operation completes and task 0 becomes the least recently run task.

❺ "prog_a" completes, passing control to task 2.

❻ "prog_c" completes, passing control to task 1.

Notice that unless both task 0 and task 2 are waiting or do not have a program to run, or task 0 or task 2 RELEASEs to task 1, task 1 is effectively blocked from execution.

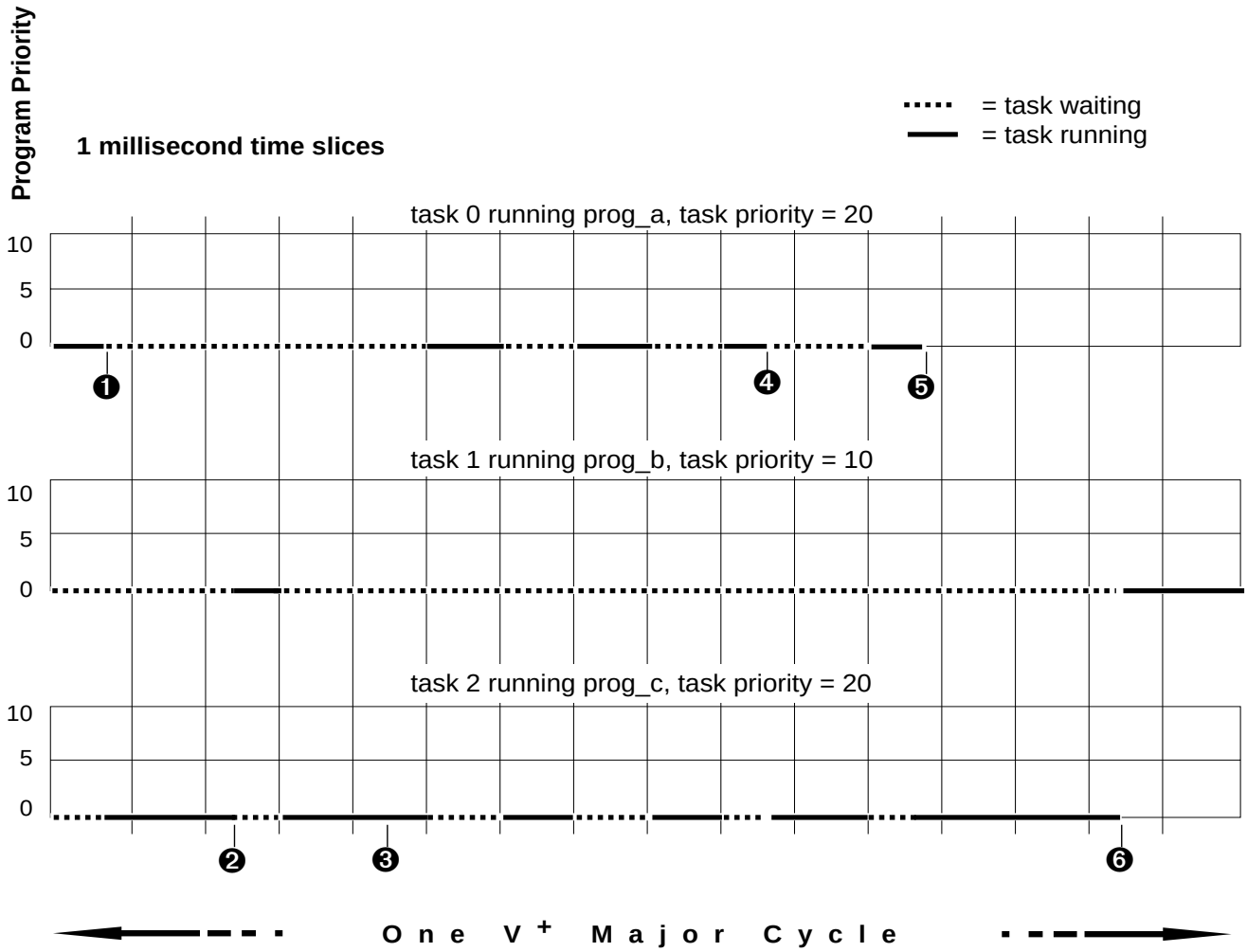

Figure 1-5. **Priority Example 1**

The numbers in this example are referenced in the text on page 32.

1.10 Default Task Configuration

System Task Configuration

The Adept V+ system has a number of internal tasks that compete with application ("user") program tasks for time within each time slice:

- On motion systems, the V+ trajectory generator runs (as the highest priority task) in slice 0 and continues through as many time slices as necessary to compute the next motion device set point.
- On motion systems, the CPU running servo code will run the servo task (at interrupt level) every 1 or 2 milliseconds.[1]
- The V+ system tasks run according to the priorities shown in Table 1-2.

Description of System Tasks

The system tasks and their functions are:

Trajectory Generator	Compute the series of set points that make up a robot motion
Terminal / Graphics	Refresh the terminal or graphics monitor display
Monitor	Service user requests entered at the monitor window (monitor commands and responses to system prompts)
Network / DDCMP	Handle implementation of DDCMP protocols for serial lines configured as DDCMP lines
Kermit	Handle implementation of Kermit protocols for serial lines configured as Kermit lines
Pendant	Handle manual control pendant I/O
Disk Driver	Handle requests for I/O to the hard and floppy disk drives
Serial I/O	Service serial I/O ports
Vision Communications	Communicate with the VIS board
Vision Analysis	Evaluate vision commands
Servo Communications	Communicate with the servo interrupt routines or the VJI or VMI boards

[1] The frequency at which the servo tasks interrupts the major cycle is set with the controller configuration utility, CONFIG_C.

Table 1-2. **System Task Priorities**

Slice	System Task										
	Trajectory Generator	Terminal / Graphics	Monitor	Network / DDCMP	Kermit	Pendant	Disk Driver	Serial I/O	Vision Communi-cations	Vision Analysis	Servo Communi-cations
0	63	0	0	0	0	0	0	0	14	13	0
1	63	0	0	0	0	0	0	0	14	13	0
2	63	0	0	0	0	0	0	0	14	13	0
3	63	0	0	0	0	0	0	0	14	13	0
4	63	0	0	0	0	0	0	0	14	13	0
5	63	0	0	0	0	0	0	0	14	13	0
6	63	0	0	0	0	0	0	0	14	13	0
7	63	0	0	0	0	0	0	0	14	13	0
8	63	0	0	0	0	0	0	0	14	13	0
9	0	0	0	0	0	0	0	0	14	13	0
10	0	0	0	0	0	0	0	0	14	13	0
11	0	0	0	0	0	0	0	0	14	13	0
12	0	0	0	0	0	0	0	0	14	13	0
13	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	50	56	0	0	55
15	0	63	62	61	60	59	58	56	0	0	0

User Task Configuration

The remaining time is allocated to the user tasks using the controller configuration utility. (See the description of "CONFIG_C" in the *Instructions for Adept Utility Programs* for details.) For each time slice, you specify which tasks may run in the slice and what priority each task has in that slice. The default priority configuration is shown in Table 1-3.

Table 1-3**. Default Task Priorities**

Slice	Task							
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7-27**
0	20	19	0	0	15	0	0	0
1	20	19	0	0	15	0	0	0
2	20	21	0	0	15	0	0	0
3	20	21	0	0	15	0	0	0
4	20	19	0	0	15	0	0	0
5	20	19	0	0	15	0	0	0
6	20	21	0	0	15	0	0	0
7	20	21	0	0	15	0	0	0
8	20	19	0	0	15	0	0	0
9	10	9	0	0	5	0	0	0
10	10	11	0	0	5	0	0	0
11	10	11	0	0	5	0	0	0
12	10	9	0	0	5	0	0	0
13	0	0	20	15	0	0	0	5
14	0	0	0	0	0	20	15	0
15	0	0	0	0	0	0	0	0

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2.1 Basic SEE Editor Operations

The SEE editor was introduced in Chapter 1. It is described in more detail in this chapter.

The following notation is used in the tables in this section:

- The control key is indicated by “Ctrl+”, the alternate key is indicated by “Alt+”, and the Shift key is indicated by “S+”. When using the shift, alternate, and control keys, they should be pressed at the **same time** as the following key.

  Some terminals on S-series systems will not have an “Alt” key, and the “Esc” key must be used instead. For example, the equivalent of “Alt+A” is “Esc” and then “A” (the escape key should be pressed and released **before** the next key is pressed).

- “<n>” indicates a number is to be entered as a command prefix (**without** the angle brackets). For example, you would enter “10L” to move the cursor to line 10.
- “<char>” indicates a character is to be entered (**without** the angle brackets). For example, you would enter “Sa” to skip to the next “a” on the line.
- Keys used only on A-series controllers are marked with an “{A}”. Keys used only with S-series terminals are marked with an “{S}”.

Cursor Movement

Tables 2-1 and 2-1 list the keys used for moving around the editor in all modes. The cursor keys can be either the cursor movement keys above the trackball or the keys on the numeric keypad when “Num lock” is not engaged.

Table 2-1. **Cursor Movement Keys With A-Series Keyboard**

Cursor Key	Without Ctrl Key	With Ctrl Key
↑	Up 1 line	Up 1/4 page
↓	Down 1 line	Down 1/4 page
→	Right 1 character	Right 1 item
←	Left 1 character	Left 1 item
Home	Top of program	
Page Up	Up 1 screen	
Page Down	Down 1 screen	
End	End of program	

The scroll bars will also move through a SEE editor program. (The bottom scroll bar has an effect only if the editor window has been sized down.) Clicking on the up/down arrows moves the program up or down a few lines. Clicking the left/right arrows moves the program left or right. Clicking in a scroll bar displays the corresponding section of the

program (e.g., clicking in the middle of the scroll bar displays the middle section of the program). Dragging a scroll handle moves the program up or down, or left or right.

Table 2-2. **Cursor Movement Keys With Wyse Terminal**

Key	Function Without Shift Key
↑	Up 1 line
↓	Down 1 line
→	Right 1 character
←	Left 1 character
Line Feed	Up 1 screen
Home	Down 1 screen
Start (PF1)	Go to start of line
<-- (PF2)	Move left 1 item
--> (PF3)	Move right 1 item
End (PF4)	Go to end of line
Top (F15)	Go to top of program
Bottom (F16)	Go to end of program

Deleting, Copying, and Moving Lines

Unlike many text editors, multiple copy operations are stored in a stack. Each copy operation places a line(s) on top of the stack. Each paste operation removes a line(s) from the top of the stack and pastes it at the current location. However, once a single line has been pasted, it is removed from the copy buffer and cannot be pasted again.

Key(s)	Action
Copy (F9)	Copy the current line into the editor's copy buffer (know as the "attach buffer").
Paste (F10)	Paste the most recently copied line above the current line. You cannot exit SEE with lines in the attach buffer. (Ctrl+K will remove lines from the copy buffer without pasting them into a program.) Lines cannot be pasted in read-only mode.
Paste All (S+F10)	Paste the entire copy buffer above the current line.
Cut (S+F9)	Cut the current line and place it in the copy buffer.
Del Line {S} Ctrl+Delete {A}	Delete the current program line and do **not** place it in the copy buffer. (Press Undo (F6) immediately after deleting to restore the line(s) just deleted.)

Text Searching and Replacing

The SEE editor can search for specific text strings, or change a specified string to another string. The following keys perform string searches and replacements.

To search for a text string:

1. Press the Find (F7) key (or press “F” in command mode).
2. Enter a search string and press ↵.
3. The text will be searched for from the cursor location to the bottom of the program (but not from the top of the program to the cursor location).
4. To repeat the search, press the Repeat (F8) key (or “'” in command mode).

To find and replace a line of text:

1. Press the Change (S+F7) key (or press “C” in command mode).
2. Enter a search string and press ↵.
3. Enter the replace string and press ↵.
4. The text will be searched for from the cursor location to the bottom of the program. Only one search and replace operation will take place at a time. “Global” search and replaces are not performed.
5. To repeat the change, press the Repeat (F8) key (or “'” in command mode).
6. To cancel the change, press the Undo (F6) key (before closing the line).

   Normally, text searches are not case-sensitive. The “EXACT” editor toggles the case-sensitivity of the search operation (see “SEE Editor Extended Commands” on page 47).

NOTE: Press the space bar to abort a search.

The latest search and replacement strings are retained between edit sessions.

Switching Programs in the Editor

The following function keys switch from editing one program to editing another program. (The internal program list mentioned below is described in the next section.)

Key(s)	Action
New (F2)	The editor prompts for the name of the new program to edit. The new program will be accessed in read-write mode unless "/R" is specified after the program name or the program is currently executing. The "home pointer" for the internal program list is set to the old program.
Go To (F3)	If the cursor is on a line containing a CALL instruction, the program referenced by the CALL is opened in the SEE editor. If the program is present on the internal program list, the previous access mode will be used. If the program is not on the program list, the editor will remain in its current access mode.
Retrieve (S+F3)	This command causes the editor to cycle through the internal program list, bringing the next program in the list into the editor. The access mode for the new program will be the same as the previous time the program was edited.
Prog_Up {S} Ctrl+Home {A} (Home key on numeric keypad)	Changes to editing a program contained on the task execution stack being accessed by the editor. When the new program is opened, its name is added to the internal program list maintained by the editor. If the execution stack is being accessed for the first time during the edit session, the editor accesses the stack for the task that most recently stopped executing (if the program debugger is not in use), or the stack for the task being debugged. The last program on the execution stack is opened for editing. If the execution stack has already been accessed, the program opened is the one that **called** the previous program accessed from the stack.
Prog_Down {S} Ctrl+End {A}	Changes to editing a program contained on the task execution stack being accessed by the editor. When the new program is opened, its name is added to the internal program list maintained by the editor. If the execution stack is being accessed for the first time during the edit session, this command acts exactly like **Prog_Up** {S} or **S**+**Home** {A} (see above). If the execution stack has already been accessed, the program opened is the one that was called by the previous program accessed from the stack.

The Internal Program List

To simplify moving from one program to another during an editing session, the SEE editor maintains an internal list of programs. The program list contains the following information (for up to 20 programs):

- Program name
- Editor access mode last used

- Number of the step last accessed
- Memorized cursor position (see the “M” command)

The program list is accessed with the SEE monitor command and program instruction, and with editor commands described in this chapter.[1]

The editor maintains two pointers into the program list:

1. The “top pointer” always refers to the program currently displayed in the edit window.
2. The “home pointer” refers to the program that was edited most recently.

The following “rules” govern the program list and its pointers.

- When a SEE monitor command is entered, one of the following occurs:
  a. If a program name is specified, the new program name is added at the top of the program list.
  b. If no program name is specified and no program task has stopped executing since the last edit session, the program list is not changed and the program at the top of the list (the last program edited) is opened.
  c. If no program name is specified and a program task **has** stopped executing since the last edit session, that program is added to the top of the program list and is displayed for editing.
- When a SEE program instruction is executed, a temporary program list is created for that editing session. The list initially includes only the current program name. The list is deleted at the end of the editing session.
- Whenever a program not already on the list is edited during an editing session (for example, pressing the New (F2) or Go To (F3) key), the new name is added at the top of the program list and the home pointer is moved to the entry for the previous program edited.
- Retrieve (S+F3) rotates the program list so the top entry moves to the bottom and all the other entries move up one position. Then the top program is displayed for editing and the home pointer is positioned at the first entry below the top of the list.
- The “H” command advances the home pointer down the list and displays the name of the program at the new position.
- The “Alt+H” command switches to editing the program marked by the home pointer, that program is moved to the top of the list, and the home pointer is moved to the entry for the previous program edited.

  If the home pointer has not been explicitly moved, “Alt+H” opens the previously edited program.

[1] The program list is cleared when the ZERO monitor command is processed.

Special Editing Situations

- You cannot modify the .PROGRAM argument list or an AUTO instruction while the program is present on a task execution stack. (A program is on the execution stack if it has been executed in that task since the last KILL or ZERO instruction.) The error message "*Invalid when program on stack*" will be displayed. To edit the line, exit the editor and remove the program from (all) the execution stack(s) in which it appears. (See the STATUS monitor command for information about how to examine the execution stacks, and the KILL monitor command for information on how to clear a stack.)

- If you enter a line of code that is longer than 80 characters, the portion of the line longer than 80 characters will not be displayed until you move the cursor along the line (or make a change to the line). Then the editor **temporarily** wraps the line and overwrites the next line on the screen. The temporarily overwritten line will be redisplayed as soon as you move off the line that is wrapping on top of it.

  NOTE: You may occasionally encounter lines that are too long for SEE to process. (Such lines can be created with an editor on another computer, or they may result from a line becoming further indented because of new surrounding control structures.)

  Any attempt to move the cursor to such a line will result in the message "*Line too long*", and the cursor will automatically move to the next line. (The "{" command [and others] can be used to move the cursor above a long line.)

  The best way to use the SEE editor to change such a line is to: (1) move the cursor to the end of the line just above the long line; (2) use **Insert mode** to insert two or more program lines that will have the same effect as the long line, **plus a blank line**; (3) with the cursor at the blank line, issue **one command** to delete the blank line and the long line (for example, **S**+**Delete** in **Command mode**).

- Whenever the cursor is moved off a program line (and when certain commands are invoked), the editor "closes" the current line. As part of that process, the line (and those following it) are displayed in standard V+ format (for example, abbreviation expansion, letter case, spacing, and line indents). When a long line is closed, the end of the line is erased from the screen and the next line is automatically redrawn. Undo (F6) will not undo changes to a closed line.

  Until a line is closed, its effect on the indenting of subsequent lines is not considered. Thus, for example, Redraw (S+F6) ignores an "un-closed" line when redrawing the display.

- In some cases, closing a line will cause its length to be increased because of abbreviation expansion and line indents. If the expanded line would be longer that the maximum line length allowed, an error message will be displayed and you will be prevented from moving off the long line. You will then have to shorten the line, break it into two or more pieces, or press Undo (F6) to restore the previous version of the line.

- Syntax is also checked when a line is closing. If an error is detected, the editor normally marks the line as a "bad line" by placing a "?" in column 1. Programs

containing “bad” lines cannot be executed. Thus, you will have to eliminate all the bad lines in a program before you will be able to execute it. (You can use the editor’s string search feature to search through a program for question marks indicating bad lines.)

NOTE: The editor provides a command (“AUTO.BAD”) that can be used to tell the editor you want to be forced to correct bad lines as soon as they are detected.

The SEE Editor in Command Mode

In addition to the key lists in Tables 2-1 and 2-1, the key strokes listed in the following table will move the cursor when the editor is in command mode.

Table 2-3. **Cursor Movement in Command Mode**

Key	Action
B	Bump window down a few lines
Esc B Ctrl+B	Go to bottom of program
T	Bump window up a few lines
Esc T Ctrl+T	Go to top of program
[	Up a line
]	Down a line
Alt+[(A-Series) {	Up a few lines
Alt+] (A-Series) }	Down a few lines
(	Up to top of window
)	Down to bottom of window
<n>L	Move to line <n>
Space	Right one character
Esc Space Tab	Right to next item
Back Space	Left one character
Esc Back Space Esc Tab	Left to previous item
Return	Go to start of next line
Esc Return	Close line and go to column 1

Table 2-3. **Cursor Movement in Command Mode** (Continued)

Key	Action
, (comma)	Go to beginning of line
. (period)	Go to end of line
<n>J	Jump to column <n>
S<char>	Skip to character <char>
;	Skip to semicolon

Table 2-4 lists the actions keystrokes will perform when the editor is in Command mode. The characters in the column labeled “Char. Codes” are defined as follows:

M — The command changes edit mode from Command mode to either Insert mode or Replace mode as indicated in the table.

(M) — The command changes the mode as indicated only until the next character is typed, and then the editor returns to Command mode.

R — The command can be executed when the program is being viewed in **read-only** mode.

Table 2-4. **SEE Editor Command Mode Operations**

Keystroke(s)	Function	Char. Codes
Editing A Line Of Text		
D	Delete a character	
I	Start character Insert mode	M
Esc I	Break line and enter Insert mode	M
R	Start character Replace mode	M
Esc	Return to Command mode	
W	Delete up to the next item	
Esc W	Delete item and start Insert mode	M
K<char>	Delete (kill) up to character <char>	
/	Replace a single character	(M)
\	Insert a single character	(M)
Ctrl+L	Convert to lowercase to end of line	
Ctrl+U	Convert to uppercase to end of line	
Esc Ctrl+B	Convert tabs to blanks (spaces)	
Esc Ctrl+T	Convert spaces to tabs	

Table 2-4. **SEE Editor Command Mode Operations** (Continued)

Keystroke(s)	Function	Char. Codes
Deleting/Copying/Moving Lines		
Esc D Ctrl+D	Delete a line	
–Esc D –Ctrl+D	Undelete last line deleted	
A	Copy line to attach buffer	R
–A	Copy line from attach buffer	
Esc A Ctrl+A	Move line to attach buffer	
–Esc A –Ctrl+A	Move line from attach buffer	
E	Dump attach buffer to program	
Esc K Ctrl+K	Delete (kill) line in attach buffer	R
Text Searching And Replacement		
F	Find a string in the program	R
C	Substitute a string in the program	
’	Repeat last Find or Change	R
0’	Display string being searched for	R
Program Operations		
N	Change to editing new program	R
H	Rotate home list and show top name	R
Esc H	Change to top program on home list	R
Ctrl+R	Change to editing program CALLed on the current line	R
Esc Ctrl+R	Change to next program on home list	R
Esc S	Change to previous program on stack	R
–Esc S	Change to next program on stack	R
Miscellaneous Operations		
Esc Ctrl+C	Cancel changes to current line	R
Esc E	Exit the editor (or the debugger)	R
Ctrl+E	Exit the editor (or the debugger)	R

Table 2-4. **SEE Editor Command Mode Operations** (Continued)

Keystroke(s)	Function	Char. Codes
G	Repeat the last S, K, Ctrl+L, or Ctrl+U command (whichever was last)	R
M	Memorize current line and column	R
–M	Return to memorized position	R
V	Refresh the full display	R
X	Initiate extended command (see below)	R
XDEBUG	Change to debugger monitor mode	R

Command Mode Copy Buffer

In command mode, a special 25-line copy buffer is maintained. This buffer is completely separate from the copy buffer described in “Deleting, Copying, and Moving Lines” on page 39 and works only when the editor is in command mode. **Del Line** {S} or **S+Delete** {A} removes lines from the program and places them in the special buffer. Preceding **Del Line** {S} or **S+Delete** {A} by a minus sign (“–”) copies the line most recently deleted (and removes it from the buffer). **Del Line** {S} and **S+Delete** {A} can be prefaced with a minus sign and a number to “undelete” a number of lines.

These keys strokes work as described only in Command mode. The copy buffer is discarded when you exit the SEE editor (but is maintained as you edit different programs without leaving the editor).

SEE Editor Extended Commands

Editor extended commands are used for infrequent operations, which do not warrant allocation to a dedicated keyboard key. The extended commands are invoked with the “X” command (in Command mode), which prompts for the name of the actual command to be performed.

The command name can be abbreviated to the shortest length that uniquely identifies the command. After the command name (or abbreviation) is entered, press ↵ to indicate the end of the name.

As indicated below, some commands display a message on the editor command line. Some of the commands prompt for additional input.

All of the following commands can be used when viewing a program in read-only mode. Most of the commands close the current line.

NOTE: The settings controlled by the extended commands are all retained between editing sessions initiated with the SEE monitor command.

When the SEE program instruction is used to initiate program editing, all the settings controlled by the extended commands are set to the "initial" settings described below. Settings changed during the edit session are not retained after the editor is exited.

AUTO.BAD — Toggles between the methods the editor uses to respond to invalid lines detected while editing.

In the first mode, such lines are flagged as "bad lines" with a question mark in column one. Editing of the program can continue normally, but the program will not be executable until all the bad lines are either corrected, deleted, or made into comment lines.

In the second mode, invalid lines must be corrected, deleted, or commented out before the line can be closed.

DEBUG — Switches from normal program editing to use of the program debugger in its monitor mode. (The debugger is described in section 2.3 on page 52.)

DSIZE — Sets the size of the "debug window" used by the program debugger (described in section 2.3).

EXACT — Toggles the case-sensitivity of text searches.

In the first mode, case is ignored when making text searches. In the second mode, text searches must match upper and lower case letters exactly for a search to be successful.

READONLY — Changes the access mode for the current program to read-only mode. (May be abbreviated "RO".)

READWRITE — Changes the access mode for the current program to read-write mode. (May be abbreviated "RW").

SEE — Switches from debug editor mode to normal (full-screen) program editing. (Also see the Edit [F7] key.)

TSIZE — In response to this command, you will be shown the current size of the display, and asked how many lines high you want the display to be. You must specify at least seven lines. (Press ↵ to retain the current setting.)

See DSIZE above for an explanation of how the TSIZE setting affects the size of the edit and debug windows displayed by the program debugger.

WHERE — Displays the current cursor column number. (The current cursor line number is always displayed on the information line at the bottom of the edit window.)

Edit Macros

Edit macros allow you to perform the same sequence of editor commands, or enter the same sequence of text characters, several times during an editing session.

Two edit macros can be defined at the same time. Either macro can be invoked from any point in the definition of the other macro, except that such linking is not permitted to be recursive. (That is, a macro cannot call itself and a called macro cannot call the other macro.)

The following commands are used to define and apply the macros. All these commands can be used when viewing a program in read-only mode but cannot perform any actions disallowed in read-only mode.

Press the space bar to abort an executing macro.

Key(s)	Action
Esc U	Define the "U" macro. The prompt "Macro (Ctrl+Z ends):" is displayed on the editor command line. Press the keys you wish to have recorded, in exactly the sequence they are to be processed to perform the desired operations. When you have finished entering the macro definition, enter Ctrl+Z.
	NOTE: It may be easier to manually perform the sequence to be recorded, writing down the keys as you press them. Then you can read from your notes as you define the equivalent macro.
U	Process the "U" macro.
0U	Display the current definition of the "U" macro.
Esc Y	Define the "Y" macro.
Y	Process the "Y" macro.
0Y	Display the current definition of the "Y" macro.

NOTE: Macro definitions are retained between editor sessions initiated with the SEE monitor command (but not between sessions initiated with the SEE program instruction).

2.2 Sample Editing Session

The following steps will create a sample V+ program and subroutine, give an example of parameter passing, and create a disk file of the sample programs.

1. With the controller on and running—make sure there are no other programs in memory by entering the command:[1]

   ```
   ZERO
   ```

[1] Memory does not have to be cleared. However, it will make this example simpler.

2. The system will ask for verification that you want to delete all programs from memory. This will delete the programs and data from system memory but will not delete the disk files.

3. Enter the command:

```
SEE sample
```

4. The system will advise you that this program does not exist and ask if you want to create it. Respond "Y ↵".

5. The SEE editor window should now be displayed. Enter insert mode by pressing the "Insert" key (Edit [F11] on a Wyse terminal).

6. Enter the following lines exactly as shown:

```
AUTO $ans

TYPE "Welcome."

CALL get_response($ans)

TYPE $ans, " is now at the keyboard."
```

7. Create the subroutine "get_response":[1]

   a. Move the cursor to the "CALL" line and press the Goto (F3) key.

   b. The message line will indicate that "get_response" does not exist and ask if you want to create it. Respond "Y ↵".

8. A new program will be opened in the SEE editor window. Enter the parameter for this subroutine by using the cursor keys to place the typing cursor between the parentheses on the program line and type "$text_param".

9. Move the cursor off the program line and enter the lines:

```
PROMPT "May I have your name please? ", $text_param

RETURN
```

10. Review your programs. The Retrieve (S+F3) key will toggle you through all the programs you have edited in the current session.

11. When you are satisfied your programs are correct, exit the SEE editor by pressing the Exit (F4) key.

12. You will now be at the system prompt. Test your program by entering the command:

```
EXECUTE sample
```

13. The program should greet you, ask for your name, and print the response on the screen. A message will then be displayed indicating the program completed.

14. If all works correctly, save your programs to a disk file by entering the command:

```
STOREP sampfile.v2
```

[1] There is no difference between a subroutine and a program.

A file will be created (using the default path specification) that will contain the two programs “sample”, and “get_response”.

15. To check that the programs were stored successfully, enter the commands:

```
ZERO

LOAD sampfile.v2

EXECUTE sample
```

The program should execute as before. See the *V+ Operating System User’s Guide* for details on the default path and options to the STORE commands.

When you are creating and modifying programs, bear in mind:

- If you load a file containing programs with the same names as programs resident in memory, the resident programs will NOT be replaced. You must delete (from memory) a program before you can load a program with the same name.
- You cannot overwrite existing disk files. A file must be deleted from disk (with FDELETE) before a file of the same name can be written to the same sub-directory. If you are making changes to existing files, we recommend the following procedure:
  a. Rename the existing file for backup:

```
FRENAME filename.bak = file_name.v2
```

  b. Store the modified files:

```
STOREP filename.v2
```

  c. When you are satisfied with the modified files, delete the backup:

```
FDELETE filename.bak
```

- If you have programs from multiple disk files resident in memory, the “module” commands will help keep the various files straight. See the descriptions of MODULE, STOREM, MIDRECTORY, and DELETEM in the *V+ Language Reference Guide.*

2.3 The Program Debugger

V+ systems include a program "debugger" for interactively executing and modifying application programs. With the debugger, a program can be executed a step at a time (or in larger, user-controlled segments) while the program instructions and the program output are simultaneously displayed in two separate sections of the monitor window.

> **NOTE:** The program debugger cannot access "protected" programs.

The debugger has an "editor mode" that allows editing of programs during the debugging session. Changes made to the program can be executed immediately to verify their correctness.

While the program is executing, the values of program variables can easily be displayed or changed.

The following sections describe the use of the program debugger in detail.

Entering and Exiting the Debugger

The program debugger can be invoked in two ways:

- From the command line with the DEBUG monitor command.
- From the SEE editor with the Debug (S+F11) key or the DEBUG extended command. (The function keys and the SEE editor extended commands are described earlier in this chapter.)

> **NOTE:** The program debugger cannot be invoked from the SEE editor when the editor has been initiated with the SEE program instruction.

When a debugging session is initiated, two aspects of the debugging session need to be established: the program task that will be accessed for program execution, and the program that will be displayed in the debugger edit window. The methods for providing this information depend on how you invoke the program debugger, as described below.

Use the Exit (F4) key (or a keyboard command) to exit the debugger and return to the V+ system monitor.

The DEBUG Monitor Command

The following command formats will invoke the debugger from the system prompt:

```
DEBUG t prog
```

`t` Initiates debugging in task number "t". If the task number is not specified, the task number will be determined as follows:

If **any** execution task has terminated execution since the start of the last debugging session, that task will be assumed.

If no task has terminated since the previous debugging session, the previous task is accessed again.

If neither of the above situations apply, the main control task (number 0) is accessed.

(Commands affecting other tasks can still be entered, but their task number will have to be specified explicitly.)

`prog` The named program is displayed in the debugger edit window in read-only editor access mode.

If the name is omitted, the program primed for the task or the last program executed by the task will be selected.

An error will result if the named program does not exist, and the DEBUG request will be aborted.

When the specified program is opened for (read-only) editing, its name is added at the top of the SEE editor internal program list.

DEBUG without any parameters is useful when:

1. You want to resume the latest debugging session.

   In this case, the edit window and the execution pointer (see Figure 2-1) will be restored as they were when the previous debugging session was ended. That is, debugging can continue as though it had not been interrupted.

2. A program has terminated execution with an error, and you want to use the debugger to investigate the cause.

   In this case, the program that failed will be displayed in the edit window, with the execution pointer positioned at the step **after** the failed step.

Using the Debug Key or the DEBUG Extended Command

While editing a program with the SEE editor, change to the program debugger by pressing the Debug (S+F11) key or by entering the DEBUG extended command. When the debugger is invoked from the SEE editor, you are asked which execution task you want to use. Then the debugger display replaces the normal SEE editor display, with the same program visible in the edit window and the specified task selected.

While using the program debugger you may decide you want to change the default task number. You can use the following steps to make that change:

1. If you are in debug monitor mode, press Edit (F11) to select debug editor mode. (The debug modes are described later in this chapter.)
2. Enter the SEE editor “DEBUG” extended command.
3. In response to the prompt, enter the desired new task number.

Exiting the Debugger

Press Exit (F4) to exit the program debugger and return to the system prompt. This command is accepted in either debug mode.

In addition, in debug editor mode (in Command mode) you can use “Alt+E” to exit to the V+ system prompt (or Esc and E if your keyboard does not have an Alt key).

The Debugger Display

Once the program debugger has been invoked, the display will look similar to that shown in Figure 2-1.

> **NOTE:** The sample shown below represents the display that would appear on A-series monitor. You will see a slightly different display on an S-series terminal.

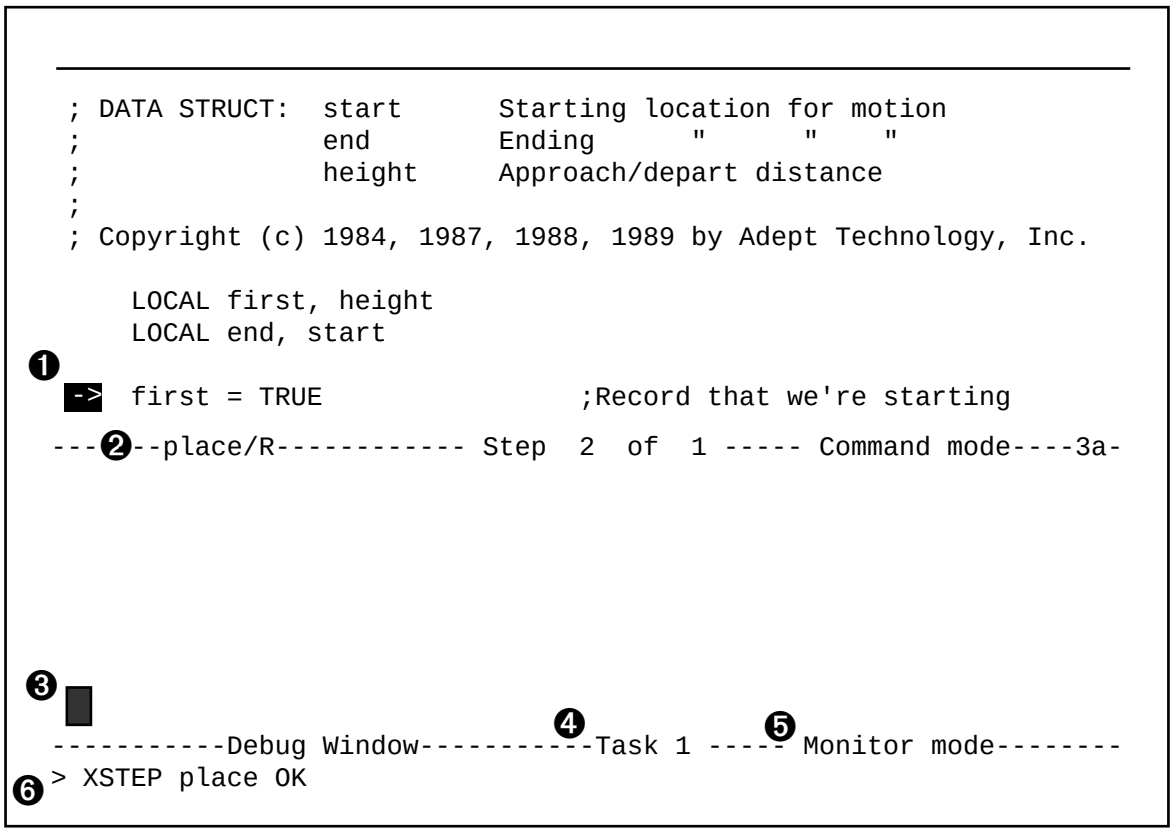
; DATA STRUCT: start Starting location for motion
; end Ending " " "
; height Approach/depart distance
;
; Copyright (c) 1984, 1987, 1988, 1989 by Adept Technology, Inc.
LOCAL first, height
LOCAL end, start
->
first = TRUE ;Record that we're starting
---❷--place/R------------ Step 2 of 1 ----- Command mode----3a-
❸
❹
❺
----------Debug Window----------Task 1 ----- Monitor mode--------
❻ > XSTEP place OK

Figure 2-1. **Example Program Debugger Display**

The following numbered list refers to the display shown in Figure 2-1.

❶ The execution pointer—indicates the next step in the program that will be executed.

❷ The editor information line—provides the same information as during a normal editing session (see Figure 1-1 on page 14). Notice that while the debugger is in monitor mode, the program will be in read-only mode. The debug window occupies the screen below this line.

❸ The typing cursor. In monitor mode, the cursor will appear in the debug window, and debug and monitor commands can be entered. Responses to

program prompts will appear here. Commands will appear below the debug information line.

❹ Shows which task the debug session is running in.

❺ Shows the debug mode. In monitor mode, debug and other monitor commands can be entered, and the program can executed. In editor mode, the typing cursor will appear in the editor window, and the program can be edited.

❻ Displays entered commands and the results of various debug operations. The ">" character serves as a prompt for user input when you are entering commands to the debugger. After processing a command, the debugger displays "ok" on the command line after the command. That acknowledges completion of the command, regardless of whether or not the command was successful. For example, the command line shown in Figure 2-1 indicates that the debugger has just processed the command "XSTEP place".

NOTE: Under some circumstances the display in the edit window can be overwritten by program or system output. Press Redraw (S+F6) key to restore the entire debugger screen.

Since the edit window can be moved to anywhere in the current program (or even to another program), this pointer may not be visible in the edit window. The edit window will move to the section of program containing this pointer whenever program execution stops for any reason.

Debugger Operation Modes

The program debugger has two modes of operation. Use the Edit (F11) and Debug (S+F11) keys (or Ctrl+E) to change modes.

Monitor mode In this mode the program in the edit window is accessed in read-only mode, and all keystrokes are interpreted as system monitor commands. System and program output is displayed in the debug window.

While in monitor mode, the program displayed in the edit window is accessed in read-only mode. As described in a later section, most of the keyboard function keys perform the same functions as with the SEE editor.

This is the initial mode when the debugger is invoked. See the section "Debug Monitor-Mode Keyboard Commands" on page 58 for a description of how monitor mode is used.

Editor mode As its name indicates, this mode enables full editing access to the program in the editor window. All the features of the SEE editor can be used in this mode.

NOTE: Programs that have been loaded from disk files with the "read-only" attribute cannot be accessed in editor read-write mode.

Debugging Programs

The basic strategy for debugging a program is:

1. Invoke the program debugger with the DEBUG monitor command, the DEBUG editor extended command, or the Debug (S+F12) key.
2. Initiate execution of the program (usually with the PRIME or XSTEP monitor commands). (This step can be performed before or after the debugger is initiated.)
3. Step through the program (executing individual steps, sections of the program, or complete subroutines) to trace the flow of program execution. (A later section of this chapter describes control of program execution while debugging.)
4. Use the Display (F5) and Teach (S+F5) keys to display and redefine the values of variables.
5. Use edit mode to perform any desired editing operations on the program.
6. Repeat steps 2 through 5 as required.
7. Exit from the debugger.

The following sections describe the debugger commands and other features of the V+ system that aid program debugging.

When using the debugger, keep in mind:

- Some system monitor commands are not accepted in debug monitor mode. (For example, the COMMANDS command is not accepted.)
- In some situations the terminal cursor will be in the edit window when you want it to be in the debug window. In debug monitor mode, the Redraw (S+F6) or Undo (F6) keys will force the cursor to the bottom line of the debug window.
- Output to the screen from the program will generally be directed to the debug window. However, if the output includes control strings to position the cursor (for example, clear the screen), the program output may appear in the edit window. The Redraw (S+F6) key will restore the normal debugger display (except in the situation described by the next item).
- When the program displays a prompt for input in the debug window and executes a PROMPT instruction, everything you type before pressing ↵ will be received by the program. Thus, you cannot issue any debugger commands at such times.

Positioning the Typing Cursor

The typing cursor is positioned in the debug window when:

- The program debugger is initiated.
- Task execution is initiated or terminated (in the later case, the edit window will be moved as required to include the execution pointer).
- The Redraw (S+F6) or Undo (F6) key is pressed in debug monitor mode.
- The debugger is switched from editor mode to monitor mode.

The typing cursor is positioned in the edit window when:

- Any function key operation—other than Redraw (S+F6) or Undo (F6)—is performed during debug monitor mode. (Note that this includes all the keys normally used to move the cursor in the edit window, such as the arrow keys.)
- The debugger is switched from monitor mode to edit mode.
- With A-series systems, the typing cursor is positioned in the edit window if you "click" the pointer device anywhere in that window.

Debugger Key Commands

Table 2-3 and Table 2-4 list all the keys interpreted as commands by the V+ SEE editor. Except for the differences described below, all the keys listed in those tables have exactly the same effect with the debugger (in either of its modes) as they do when used with the SEE editor (detailed earlier in this chapter).

> **NOTE:** While using the debugger, the following keys are particularly useful for moving to different programs on the execution stack for the task being debugged: **Prog Up** and **Prog Down** {S}, and **Ctrl**+**Home** and **Ctrl**+**End** {A}.

The following function keys are interpreted differently by the program debugger and the SEE editor.

Edit (F11) — When the debugger is in monitor mode, this key causes editor mode to be selected. This key has its normal editor function (selection of editor Command mode) when in editor mode.

Undo (F6) — When the debugger is in monitor mode, this key simply moves the typing cursor to the bottom of the debug window.

Teach (S+F5) — Initiates changing the value of the variable at the cursor position.

> **NOTE:** This command cannot be used while the editor is in read-write access mode. You can use the READONLY or RO extended command to select read-only mode.

As with Display (F5), the typing cursor is used to point to the variable of interest. Pressing Teach (S+F5) causes the current value of the variable to be displayed in the debug window and a prompt for a new value to be assigned to the variable.

For real-valued variables, the new value can be input as a constant, a variable name, or an expression.

For location variables, the new value can be input as a location function (for example, HERE or TRANS) or a variable name. Also, a compound transformation can be specified when accessing a transformation variable.

For string variables, the new value can be input as a string constant, variable name, or expression.

Debug Monitor-Mode Keyboard Commands

The V+ program debugger allows you to interactively execute and edit the program being debugged. The commands described below can be used (in debug monitor mode) to control execution of the program being debugged (see "Control of Program Execution" on page 59).

> **NOTE:** All the commands described below (except Ctrl+E) require debug monitor mode for their use.
>
> Be careful **not to enter Ctrl+O or Ctrl+S while using the debugger**. These control characters disable output to the terminal until a second Ctrl+O or a Ctrl+Q is input.

The following terms are used below when showing equivalent monitor commands:

current_program — Refers to the program displayed in the edit window.

current_step — Refers to the program step at which the "movable cursor" is positioned. (Note that even when the terminal cursor is visible in the debug window or on the command line, the position of the "movable cursor" is still retained by the debugger.)

debug_task — Refers to the task number shown on the information line of the debug window.

Key(s)	Action
Ctrl+B	Set a breakpoint at the step indicated by the "typing cursor" (also see Ctrl+N below). (The use of breakpoints is described in "Program Breakpoints" on page 60.) This command is equivalent to the following system monitor command: `BPT @current_program current_step`
Ctrl+E	Alternate between debug modes. This command is equivalent to the Edit (F12) and Debug (S+F12) function keys, depending on the current debugger mode. (Use Ctrl+E with terminals that do not have the equivalent function keys. Use Esc and then E to exit from the editor to the V+ system prompt.
Ctrl+G	Perform an XSTEP command for the instruction step indicated by the "typing cursor". This command is equivalent to the following system monitor command: `XSTEP debug_task,,current_step`
Ctrl+N	Cancel the breakpoint at the step indicated by the "typing cursor" (see Ctrl+B above). This command is equivalent to the following system monitor command: `BPT @current_program -current_step`

Key(s)	Action
Ctrl+P	PROCEED execution of the current task from the current position of the "execution pointer". This command is equivalent to the following system monitor command: `PROCEED debug_task`
Ctrl+X	Perform an XSTEP command for the current task from the current position of the "execution pointer". This command is equivalent to the following system monitor command: `XSTEP debug_task`
Ctrl+Z	Perform an SSTEP command for the current task from the current position of the "execution pointer". This command is equivalent to the following system monitor command: `SSTEP debug_task`

Using a Pointing Device With the Debugger

On A-series controllers, double clicking on a variable or expression will display the value of the variable or expression. (If program execution has not progressed to the point where a variable has been assigned a value, double clicking on the variable may return an undefined value message.)

Control of Program Execution

While debugging programs, you will want to pause execution at various points to examine the status of the system (e.g., to display the values of program variables).

The following paragraphs describe how to control execution of the program being debugged.

> **NOTE:** Except for the special debugger commands mentioned below, all the following techniques can be used even when the program debugger is not in use.

Single-Step Execution

The debugger Ctrl+X command provides a convenient means for having program execution stop after each instruction is processed. Each time Ctrl+X is entered, a V+ XSTEP command is processed for the program being debugged.

The debugger Ctrl+Z command is provided to allow you to "step across" subroutine calls. Each time Ctrl+Z is entered, an SSTEP command is processed for the program being debugged. Thus, when the execution pointer is positioned at a CALL or CALLS instruction, typing Ctrl+Z will cause the entire subroutine to be executed, and execution will pause at the step following the subroutine call. (Ctrl+Z acts exactly like Ctrl+X when the current instruction is not a subroutine call.)

> **NOTE:** You cannot single-step "into" a subroutine that was loaded from a "protected" disk file. Thus, you must use Ctrl+Z to step across any CALL of such a routine.

> **NOTE:** The execution pointer ("–>") will not be displayed while the system is executing an instruction. Do not type a Ctrl+X or Ctrl+Z until the execution pointer reappears.

PAUSE Instructions

Debug editor mode can be used to insert PAUSE instructions in the program at strategic points. Then execution will pause when those points are reached. After the pause has occurred, and you are ready to have execution resume, you can use the PROCEED command.

The debugger Ctrl+P command provides a convenient means of issuing a PROCEED command for the program being debugged.

The disadvantage of using PAUSE instructions, however, is that they must be explicitly edited into the program, and later removed when debugging is completed. The following section describes a more convenient way to achieve the same effect as a PAUSE instruction.

Program Breakpoints

The V+ BPT command can be used to attach a "breakpoint" to an instruction. The BPT allows either or both of the following responses to occur when the breakpoint is encountered during execution:

- Execution stops at the flagged instruction (before it is executed).
- Values are displayed on the system terminal, showing the current status of user-specified expressions.

To set breakpoints at various points in the program, enter the appropriate BPT commands on the debugger command line to place the breakpoints and to specify expressions to be evaluated when the breakpoints are encountered.

If you do not need to have an expression evaluated at a breakpoint, you can use the debugger Ctrl+B command to set a "pausing" breakpoint—that is, one that will cause execution to stop. To use the Ctrl+B command you must position the typing cursor in the edit window so it is on the instruction of interest. Once the cursor is positioned, you can type Ctrl+B to have a breakpoint placed at that instruction.

> **NOTE:** You can use Go To (F3) (and other editor commands) to change the program in the edit window. Thus, you can move to any program you want before typing Ctrl+B to set a breakpoint. (You do **not** have to explicitly change back to having the edit window show the program currently stopped. The debugger will automatically display the appropriate program the next time execution stops for any reason.)

When program execution stops at a breakpoint, you can use the debugger Ctrl+N command to cancel the breakpoint at the instruction. Or you can leave the breakpoint set. In either case, you can type Ctrl+P when you are ready to have program execution resume.

> **NOTE:** A BPT command with no parameters will clear the breakpoints in all the programs in the system memory (except those programs that are executing). Entering a BPT command with no parameters in debug monitor mode will clear breakpoints in the current program.

Program Watchpoints

The V+ WATCH command attaches a "watchpoint" to a variable or user-specified expression. When a watchpoint has been set, the specified variable or expression is examined before each program instruction is executed by the task associated with the watchpoint. The value determined is compared with the value recorded when the watchpoint was originally defined. If the value has changed, the task is stopped and the old and new values are displayed.

> **NOTE:** Processing watchpoints consumes a lot of execution time and can significantly slow down program execution. Be sure to cancel all the watchpoints for an execution task after you are through using the task for debugging.

There is no shorthand debugger command for setting watchpoints, but WATCH commands can be entered on the debugger command line.

3 Data Types and Operators

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3.1 Introduction

This chapter describes the data types used by V+.

Dynamic Data Typing and Allocation

V+ does not require you to declare variables or their data types. The first use of a variable will determine its data type and allocate space for that variable. You can create variables and assign them a type as needed. The program instruction:

```
real_var = 13.65
```

will create the variable "real_var" as a real variable and assign it the value 13.65 (if the "real_var" had already been created, the instruction will merely change its value).

Numeric, string, and transformation arrays up to three dimensions can be declared dynamically.

Variable Name Requirements

The requirements for a valid variable name are:

1. Adept reserved keywords by cannot be used. Chapter 1 of the *V+ Language Reference Guide* lists the basic keywords reserved by Adept. If you have AdeptVision VME, Chapter 1 of the *AdeptVision Reference Guide* lists the additional reserved words used by the vision system.
2. The first character of a variable name must be a letter.
3. Allowable characters after the first character are letters, numbers, periods, and the underline character.
4. Only the first 15 characters in a variable name are significant.

The following are all valid variable names:

```
x    count     dist.to.part.33    ref_frame
```

The following names are invalid for the reasons indicated:

```
3x        (first character not a letter)
one&two   (”&” is an invalid name character)
pi        (reserved word)
this_is_a_long_name     (too many characters)
```

All but the last of these invalid names would be rejected by V+ with an error message. The extra-long name would be truncated (without warning) to "this_is_a_long_".

3.2 String Data Type

Variable names are preceded with a “$” sign to indicate that they contain string data.[1] The program instruction:

```
$string_name = "Adept V+"
```

allocates the string variable “string_name” (if it had not previously been allocated) and assigns it the value “Adept V+”. Numbers can be used as strings with a program instruction such as:

```
$numeric_string = "13.5"
```

where “numeric _string” is assigned the value “13.5”. The program instruction:

```
$numeric_string = 13.5
```

will result in an error since you are attempting to assign a real value to a string variable.

The following restrictions apply to string constants (e.g., "a string"):

- ASCII values 32 (space) to 126 (~) are acceptable
- ASCII 34 (") cannot be used in a string

Strings can contain from 0 to 128 characters. String variables can contain values from 0 to 255 (see Appendix C for the interpretation of the full character set).

The following are all valid names for string variables:

```
$x   $process  $prototype.names   $part_1
```

The following names are invalid for strings for the reasons indicated:

```
$3x           (first character not a letter)
$one-two      (”-” is an invalid name character)
factor        (”$” prefix missing)
$this_is_a_long_name    (too many characters)
```

All but the last of these invalid names would be rejected by V+ with an error message. The extr- long name would be truncated (without warning) to “$this_is_a_long_”.

ASCII Values

An ASCII value is the numeric representation of a **single** ASCII character. (See Appendix C for a complete list of the ASCII character set.) An ASCII value is specified by prefixing a character with an apostrophe (“'”). Any ASCII character from the space character (decimal value 32) to the tilde character (“~”, decimal value 126) can be used as an ASCII constant. Thus, the following are valid ASCII constants:

```
'A   '1   'v   '%
```

Note that the ASCII value '1 (decimal value 49) is not the same as the integer value 1 (decimal value 1.0). Also, it is not the same as the string value “1”.

[1] The dollar sign is not considered in the character count of the variable name.

Functions That Operate on String Data

Table 5-1 on page 99 summarizes the V+ functions that operate on string data.

3.3 Real and Integer Data Types

Numbers that have a whole number and a fractional part (or mantissa and exponent if the value is expressed in scientific notation) belong to the data type “real”. Numeric values having only a whole number belong to the data type “integer”. In general, V+ does not require you to differentiate between these two data types. If an integer is required and you supply a real, V+ will promote the real to an integer by rounding (not truncation). Where real values are required, V+ considers an integer a special case of a real that does not have a fractional part. The default real type is a signed, 32-bit IEEE single-precision number. Real values can also be stored as 64-bit IEEE double-precision numbers if they are specifically typed using the DOUBLE instruction (see section 3.6 for additional details).

The range of integer values is:

–16,777,216 to 16,777,215

The range of single-precision real values is:

$\pm 3.4 * 10^{38}$

The range of double-precision real values is:

$\pm 1.8 * 10^{307}$

Numeric Representation

Numeric values can be represented in the standard decimal notation or in scientific notation as illustrated above.

Numeric values can also be represented in octal, binary, and hexadecimal form. Table 3-1 shows the required form for each integer representation.

Table 3-1. **Integer Value Representation**

Prefix	Example	Representation
none	–193	decimal
^B	–^B1001	binary (maximum of 8 bits)
^	^346	octal
^H	^H-23FF	hexadecimal

Numeric Expressions

In almost all situations where a numeric value of variable can be used, a numeric expression can also be used. The following examples all result in "x" having the same value.

```
x = 3
x = 6/2
x = SQRT(9)
x = SQR(2) - 1
x = 9 MOD 6
```

Logical Expressions

V+ does not have a specific logical (boolean) data type. Any numeric value, variable, or expression can be used as a logical data type. V+ considers 0 to be false and any other value to be true. When a real value is used as a logical data type, the value is first promoted to an integer.

Logical Constants

There are four logical constants, TRUE and ON that will resolve to –1, and FALSE and OFF that will resolve to 0. These constants can be used anywhere a boolean expression is expected.

A logical value, variable, or expression can be used anywhere a decision is required. In this example, an input signal is tested. If the signal is on (high) the variable "dio.sample" is given the value true, and the IF clause executes. Otherwise, the ELSE clause executes:

```
dio.sample = SIG(1001)
IF dio.sample THEN

     ; Steps to take when signal is on (high)

ELSE

     ; Steps to take when signal is off (low)

END
```

Since a logical expression can be used in place of a logical variable, the first two lines of this example could be combined to:

```
IF SIG(1001) THEN
```

Functions That Operate on Numeric Data

Table 5-2 on page 101 summarizes the V+ functions that operate on numerical data.

3.4 Location Data Types

This section gives a brief explanation of location data. Chapter 7 covers locations and their use in detail.

Transformations

A data type particular to V+ is the transformation data type. This data type is a collection of several values that uniquely identify a location in Cartesian space.

The creation and modification of location variables are discussed in Chapter 7.

Precision Points

Precision points are a second data type particular to V+. A precision point is a collection of joint angles and translational values that uniquely identify the position and orientation of a robot. The difference between transformation variables and precision-point variables will become more apparent when robot motion instructions are discussed in Chapter 7.

3.5 Arrays

V+ supports arrays of up to three dimensions. Any V+ data type can be stored in an array. Like simple variables, array allocation (and typing) is dynamic. Unless they are declared to be AUTOmatic, array sizes do not have to be declared.

For example:

```
array.one[2] = 36
```

allocates space for a one-dimensional array named “array.one” and places the value 36 in row two of the array. (The numbers inside the brackets ([ ]) are referred to as “indices.” An array index can also be a variable or an expression.)

```
$array.two[4,5] = "row 4, col 5"
```

allocates space for a two-dimensional array named “array.two” and places “row 4, col 5” in row four, column five of the array.

```
array.three[2,2,4] = 10.5
```

allocates space for a three-dimensional array named “array.three” and places the value 10.5 in row two, column two, range four.

If any of the above instructions were executed and the array had already been declared, the instruction would merely place the value in the appropriate location. If a data type different from the one the array was originally created with is specified, an error will result.

Arrays are allocated in blocks of 16. Thus, the instruction:

```
any_array[2] = 50
```

will result in allocation of array elements 0 - 15. The instructions:

```
any_array[2] = 50
any_array[20] = 75
```

will result in the allocation of array elements 0 - 31.

Array allocation is most efficient when the highest range index exceeds the highest column index, and the highest column index exceeds the highest row index. (Row is the first element, column is the second element, and range is the third element.)

3.6 Variable Classes

In addition to having a data type, variables belong to one of three classes, GLOBAL, LOCAL, or AUTOMATIC. These classes determine how a variable can be altered by different calling instances of a program.

Global Variables

This is the default class. Unless a variable has been specifically declared to be LOCAL or AUTO, a newly created variable will be considered global. Once a global variable has been initialized (see below), it is available to any executing program[1] until the variable is deleted or all programs that reference it are removed from system memory (with a DELETE or ZERO instruction). Global variables can be explicitly declared with the GLOBAL program instruction.

Global variables are very powerful and should be used carefully and consciously. If you cannot think of a good reason to make a variable global, good programming practice dictates that you declare it to be LOCAL or AUTO.

> **NOTE:** For double-precision real variables to be global, they must be explicitly declared as global in each program they are used in:
>
> ```
> GLOBAL DOUBLE dbl_real_var
> ```

Local Variables

Local variables are created by a program instruction similar to:

```
LOCAL the_local_var
```

where the variable “the_local_var” is created as a local variable. Local variables can be changed only by the program they are declared in.

An important difference between local variables in V+ and local variables in most other high-level languages is that V+ local variables are local to all copies (calling instances) of a program, not just a particular calling instance of that program. This distinction is critical if you write recursive programs. In recursive programs you will generally want to use the next variable class, AUTO.

Automatic Variables

Automatic variables are created by a program instruction similar to:

```
AUTO the_auto_var
```

where “the_auto_var” is created as an automatic variable. Automatic variables can be changed only by a particular calling instance of a program.

> **NOTE:** If LOCAL or AUTO variables are to be double precision, the DOUBLE keyword must be used:
>
> ```
> AUTO DOUBLE dbl_auto_var
> ```

[1] Unless the program has declared a LOCAL or AUTO variable with the same name.

Automatic variables are more like the local variables of other high-level languages. If you are writing programs using a recursive algorithm, you will most likely want to use variables in the automatic class.

Scope of Variables

The “scope” of a variable refers to the range of programs that can “see” that variable. Figure 3-1 shows the scope of the different variable classes. A variable can be altered by the program(s) indicated in the shaded area of the box it is in plus any programs that are in smaller boxes. When a program declares an AUTO or LOCAL variable, any GLOBAL variables of the same name created in other programs are not accessible.

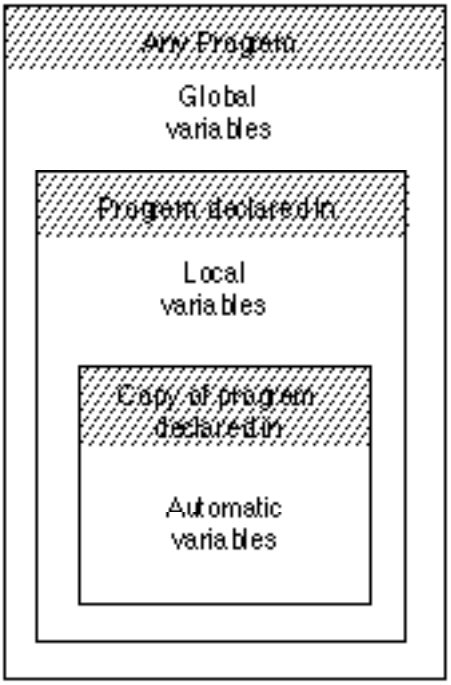

Figure 3-1. **Variable Scoping**

Figure 3-2 shows an example of using the various variable classes. Notice that:

- “prog_1” declares “a” to be GLOBAL. Thus, it is available to all programs not having an AUTO or LOCAL “a”.
- “prog_2” creates an undeclared variable “b”. By default, “b” is GLOBAL and available to other programs not having a LOCAL or AUTO “b”.
- “prog_3” declares an AUTO “a” and will not be able to use GLOBAL “a”. After “prog_3” completes, the value of AUTO “a” is deleted.
- “prog_4” declares a LOCAL “a” and, therefore, will not be able to use GLOBAL “a”. Unlike the AUTO “a” in “prog_3”, however, the value of LOCAL “a” is stored and is available for any future CALLs to “prog_4”.

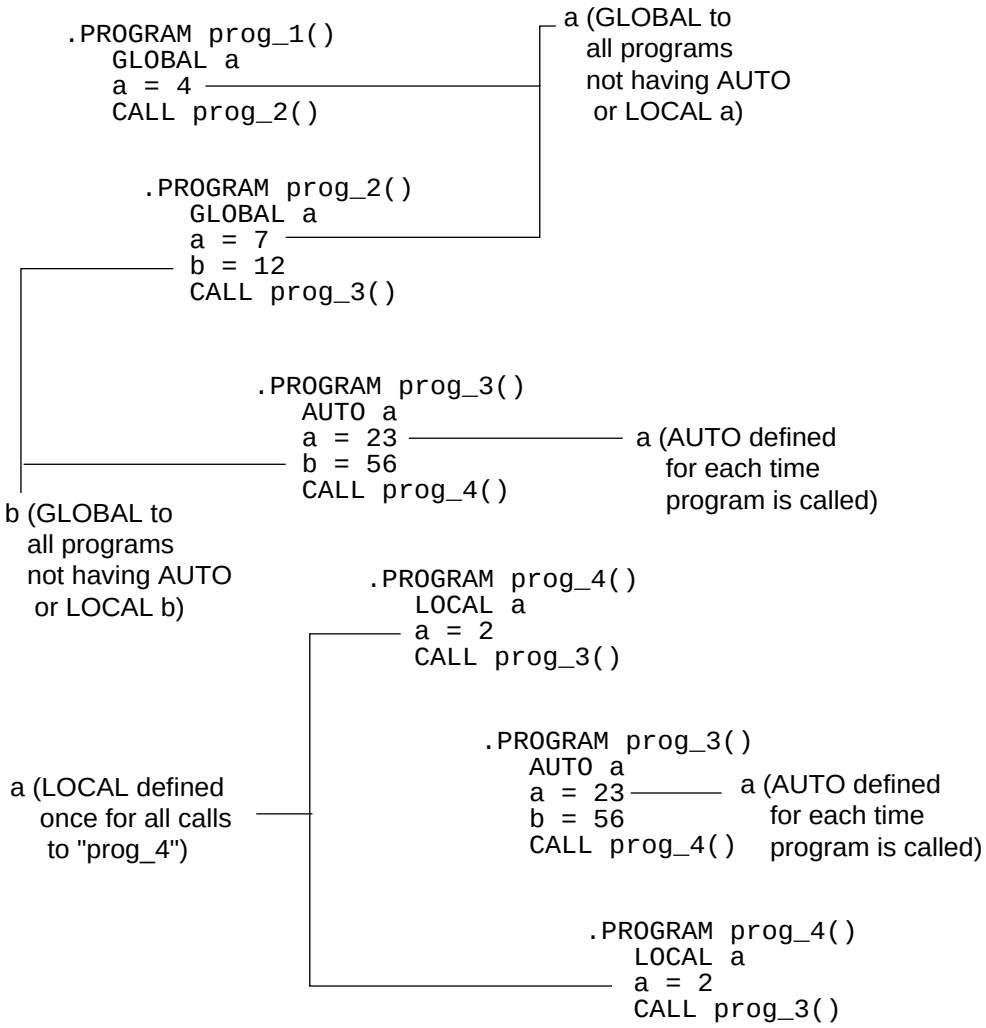

Figure 3-2. **Variable Scope Example**

Variable Initialization

Before a variable can be used it must be initialized. String and numeric variables can be initialized by placing them on the left side of an assignment statement. The statements:

```
var_one = 36

$var_two = "two"
```

will initialize the variables “var_one” and “$var_two”.

```
var_one = var_two
```

will initialize “var_one” **if** “var_two” has already been initialized. Otherwise, an undefined value error will be returned. A variable can never be initialized on the right side of an assignment statement (“var_two” could never be initialized by the above statement).

The statement:

```
var_one = var_one + 10
```

would be valid only if “var_one” had been initialized in a previous statement.

Strings, numeric variables, and location variables can be initialized by being loaded from a disk file.

Strings and numeric variables can be initialized with the PROMPT instruction.

Transformations and precision points can be initialized with the SET or HERE program instructions. They can also be initialized with the HERE and POINT monitor commands, or with the TEACH monitor command and the manual control pendant.

3.7 Operators

Assignment Operator

The equal sign (=) is used to assign a value to a numeric or string variable. The variable being assigned a value must appear by itself on the left side of the equal sign. The right side of the equal sign can contain any variable or value of the same data type as the left side, or any expression that resolves to the same data type as the left side. Any variables used on the right side of an assignment operator must have been previously initialized.

Location variables require the use of the SET instruction for a valid assignment statement (see Chapter 7). The instruction:

```
loc_var1 = loc_var2
```

is unacceptable for location and precision-point variables.

Mathematical Operators

V+ uses the standard mathematical operators shown in Table 3-2.

Table 3-2. **Mathematical Operators**

Symbol	Function
+	addition
–	subtraction or unary minus
*	multiplication
/	division
MOD	modular (remainder) division

Relational Operators

Relational operators are used in expressions that yield a boolean value. The resolution of an expression containing a relational operator will always be –1 (true) or 0 (false) and will tell you if the specific relation stated in the expression is true or false. The most common use of relational expressions is with the control structures discussed in Chapter 4.

V+ uses the standard relational operators shown in Table 3-3.

Table 3-3. **Relational Operators**

Symbol	Function
==	equal to
<	less than
>	greater than
<= or =<	less than or equal to
>= or =>	greater than or equal to
<>	not equal to

If “x” has a value of 6 and “y” has a value of 10, the following boolean expressions would resolve to –1 (true):

```
x < y
y >= x
y <> x
```

and these expressions would resolve to 0 (false):

```
x > y
x <> 6
x == y
```

Note the difference between the assignment operator “=” and the relational operator “==”:

```
z = x == y
```

In this example, “z” will be assigned a value of 0 since the boolean expression “x == y” is false and would therefore resolve to 0. A relational operator will never change the value of the variables on either side of the relational operator.

Logical Operators

Logical operators affect the resolution of a boolean variable or expression, and combine several boolean expressions so they resolve to a single boolean value.

V+ uses the standard logical operators shown in Table 3-4.

Table 3-4. **Logical Operators**

Symbol	Effect
NOT	Complement the expression or value; makes a true expression or value false and vice versa
AND	Force two or more expressions to resolve to true before the entire expression is true
OR	Force at least one expression to resolve to true before the entire expression is true
XOR	One expression must be true and one must be false before the entire expression is true.

If “x” = 6 and “y” = 10, the following expressions will resolve to –1 (true):

```
NOT(x == 7)
(x > 2) AND (y =< 10)
```

And these expressions will resolve to 0 (false):

```
NOT(x == 6)
(x < 2) OR (y > 10)
```

Bitwise Logical Operators

Bitwise logical operators operate on pairs of integers. The corresponding bits of each integer are compared and the result is stored in the same bit position in a third binary number. Table 3-5 lists the V+ bitwise logical operators.

Table 3-5. **Bitwise Logical Operators**

Operator	Effect
BAND	Each bit is compared using "and" logic. If both bits are 1, then the corresponding bit will be set to 1. Otherwise, the bit is set to 0.
BOR	Each bit is compared using "or" logic. If either bit is 1, then the corresponding bit will be set to 1. If both bits are 0, the corresponding bit will be set to 0.
BXOR	Each bit is compared using "exclusive or" logic. If both bits are 1 or both bits are 0, the corresponding bit will be set to 0. When one bit is 1 and the other is 0, the corresponding bit will be set to 1.
COM	This operator works on only one number. Each bit is "complemented": 1s become 0s and 0s become 1s.

Examples:

```
x = ^B1001001 BAND ^B1110011
```

results in "x" having a value of ^B1000001.

```
x = COM ^B100001
```

results in "x" having a value of ^B11110.

3.8 String Operator

Strings can be concatenated (joined) using the plus sign. For example:

```
$name = "Adept "
$incorp = ", Inc."
$coname = $name + "Technology" + $incorp
```

results in the variable "$coname" having the value "Adept Technology, Inc.".

3.9 Order of Evaluation

Expressions containing more than one operator are not evaluated in a simple left to right manner. Table 3-6 lists the order in which operators are evaluated. Within an expression, functions are evaluated first with expressions within the function evaluated according to the table.

The order of evaluation can be changed using parentheses. Operators within each pair of parentheses, starting with the most deeply nested pair, are completely evaluated according to the rules in Table 3-6 before any operators outside the parentheses are evaluated.

Operators on the same level in the table are evaluated strictly left to right.

Table 3-6. **Order of Operator Evaluation**

Operator
NOT, COM
– (Unary minus)
*, /, MOD, AND,BAND
+, –, OR, BOR, XOR, BXOR
==, <=, >=, <, >, <>

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4.1 Introduction

This chapter introduces the structures available in V+ to control program execution. These structures include the looping and branching instructions common to most high-level languages as well as some instructions specific to V+.

4.2 Unconditional Branch Instructions

There are three unconditional branching instructions in V+:

GOTO

CALL

CALLS

GOTO

The GOTO instruction causes program execution to branch immediately to a program label instruction somewhere else in the program. The syntax for GOTO is:

GOTO label

label is an integer entered at the beginning of a line of program code. **label** is not the same as the program step numbers: Step numbers are assigned by the system; labels are entered by the programmer as the opening to a line of code. In the next code example, the numbers in the first column are program step numbers (these numbers are not displayed in the SEE editor). The numbers in the second column are program labels.

```
61       .
62       GOTO 100
63       .
64       .
65  100  TYPE "The instruction GOTO 100 got me here."
66       .
```

A GOTO instruction can branch to a label before or after the GOTO instruction.

GOTO instructions can make program logic difficult to follow and debug, especially in a long, complicated program with many subroutine calls. Use GOTO instructions with care. A common use of GOTO is as an “EXIT routine” or “EXIT on error” instruction.

CALL

The CALL and CALLS instructions are used in V+ to implement subroutine calls. The CALL instruction causes program execution to be suspended and execution of a new program to begin. When the new program has completed execution, execution of the original program will resume at the instruction after the CALL instruction. The details of subroutine creation, execution, and parameter passing are covered in section 1.8 on page 23. The simplified syntax for a CALL instruction is:

`CALL program (``arg_list`**`)`**

`program` is the name of the program to be called. The program name must be specified exactly, and the program being CALLed must be resident in system memory.

`arg_list` is the list of arguments being passed to the subroutine. These arguments can be passed either by value or by reference and must agree with the arguments expected by the program being called. Subroutines and argument lists are described in section 1.8 on page 23.

The code:

```
48      .
49      CALL check_data(locx, locy, length)
50      .
```

will suspend execution of the calling program, pass the arguments “locx”, “locy”, and “length” to program “check_data”, execute “check_data”, and (after “check_data” has completed execution) resume execution of the calling program at step 50.

CALLS

The CALLS instruction is identical to the CALL instruction except for the specification of **`program`**. For a CALLS instruction, **`program`** is a string value, variable, or expression. This allows you to call different subroutines under different conditions using the same line of code. (These different subroutines must have the same `arg_list`.)

The code:

```
47      .
48      $program_name = $program_list[program_select]
49      CALLS $program_name(length, width)
50      .
```

will suspend execution of the calling program, pass the parameters “length” and “width” to the program specified by array index “program_select” from the array “$program_list”, execute the specified program, and resume execution of the calling program at step 50.

4.3 Program Interrupt Instructions

V+ provides several ways of suspending or terminating program execution. A program can be put on hold until a specific condition becomes TRUE using the WAIT instruction. A program can be put on hold for a specified time period or until an event is generated in another task by the WAIT.EVENT instruction. A program can be interrupted based on a state transition of a digital input signal with the REACT and REACTI instructions. Program errors can be intercepted and handled with a REACTE instruction. Program execution can be terminated with the HALT, STOP, and PAUSE commands. These instructions will interrupt the program they are contained in. Any programs running as other tasks will not be affected. Robot motion can be controlled with the BRAKE, BREAK, and DELAY instructions. (The ABORT and PROCEED monitor commands can also be used to suspend and proceed programs.)

WAIT

WAIT suspends program execution until a condition (or conditions) becomes true.

```
WAIT SIG(1032, -1028)
```

will delay execution until digital input signal 1032 is “on” and 1028 is “off.”

```
WAIT TIMER(1) > 10
```

will suspend execution until timer 1 returns a value greater than 10.

WAIT.EVENT

The instruction:

```
WAIT.EVENT , 3.7
```

will suspend execution for 3.7 seconds. This wait is more efficient than waiting on a timer (as in the previous example) since the task does not have to loop continually checking the timer value.

The instruction:

```
WAIT.EVENT
```

will suspend execution until another task issues a SET.EVENT instruction to the waiting task. If the SET.EVENT does not occur, the task will wait indefinitely.

REACT, REACTI

When a REACT or REACTI instruction is encountered, the program will begin monitoring a digital input signal specified in the REACT instruction. This signal is monitored in the background with program execution continuing normally until the specified signal transitions. When (and if) a transition is detected, the program will suspend execution at the currently executing step. REACT and REACTI suspend execution of the current program and call a specified subroutine. Additionally REACTI issues a BRAKE instruction to immediately stop the current robot motion.

Both instructions specify a subroutine to be run when the digital transition is detected. After the specified subroutine has completed, program execution will resume at the step executing when the digital transition was detected.

Digital signals 1001 - 1012 and 2001 - 2008 can be used for REACT instructions.

The signal monitoring initiated by REACT/REACTI is in effect until another REACT/REACTI or IGNORE instruction is encountered. If the specified signal transition is not detected before an IGNORE or second REACT/REACTI instruction is encountered, the REACT/REACTI instruction will have no effect on program execution.

The syntax for a REACT or REACTI instruction is:

REACT signal_number, program, priority

signal_number digital input signal in the range 1001 to 1012 or 2001 to 2008.

program the subroutine (and its argument list) that is to be executed when a react is initiated.

priority number from 1 to 127 that indicates the relative importance of the reaction.

The following code implements a REACT routine:

```
35      ; Look for a change in signal 1001 from "on" to "off".
36      ;    Call subroutine "alarm" if a change is detected.
37      ;    Set priority of "alarm" to 10 (default would be 1).
38      ;    The main program has default priority of 0.
39
40           REACT -1001, alarm, 10
41
42      ; REACT will be in effect for the following code
43
44           MOVE a
45           MOVE b
46           LOCK 20   ;Defer any REACTions to "alarm"
47           MOVE c
48           MOVE d
49           LOCK 0    ;Allow REACTions
50           MOVE e
51
52      ; Disable monitoring of signal 1001
53
54           IGNORE -1001
55  .
```

If signal 1001 transitions during execution of step 43, step 43 will complete, the subroutine "alarm" will be called, and execution will resume at step 44.

If signal 1001 transitions during execution of step 47, steps 47, 48, and 49 will complete (since the program had been given a higher priority than REACT), the subroutine "alarm" will be called, and execution will resume at step 50.[1]

REACTE

REACTE enables a reaction program that is run whenever a system error that would cause program execution to terminate is encountered. This includes all robot errors, hardware errors, and most system errors (it does NOT include I/O errors).

Unlike REACT and REACTI, REACTE cannot be deferred based on priority considerations. The instruction:

```
REACTE trouble
```

will enable monitoring of system errors and execute the program "trouble" whenever a system error is generated.

REACTE and Power Failures

In systems equipped with the optional battery back-up module,[2] system state is saved when power fails and is automatically restored when power is restored. All aspects of the system are saved except:

- Pending serial writes fail and the I/O buffer is flushed.
- Robots are stopped immediately, high power is disabled, and the robot is left uncalibrated. In order to recover a motion system after a power failure, the REACTE routine (see below) must recalibrate the motion device.

When a system starts backup after a power failure:

- Serial I/O is terminated with error –667 "*Power failure detected*".
- If a REACTE was active at power failure, it will complete and a REACTE based on the power failure will be queued.
- If a REACTE is enabled but not active, a REACTE based on the power failure will be executed.
- The REACTE based on the power failure will return error –667, "*Power failure detected*". If a REACTE is not enabled, the power failure is ignored.
- Any disk I/O that was in progress completes (make sure floppy disks are not removed or exchanged during power down).
- Graphics operations are restored.

---

[1] The LOCK instruction can be used to control execution of a program after a REACT or REACTI subroutine has completed.

[2] A position on the controller configuration DIP switch enables or disables recovery and restart from a power failure. If switch position 2 is "on", the controller will reinitialize and not attempt the recovery. If switch position 2 is "off", the recovery described above will be attempted (see the *Adept MV Controller User's Guide* for details on setting this switch).

- Digital I/O signals are reset. (If external devices are being controlled by digital output signals, make sure the REACTE routine returns digital output signals to a safe state.)
- All programs continue execution.

If the controller power switch is turned off, or the length of the power down exceeds the battery capacity, system state is lost and cannot be restored.

HALT, STOP, PAUSE

When a HALT instruction is encountered, program execution is terminated, and any open serial or disk units are DETACHED and FCLOSEd. PROCEED or RETRY will not resume execution.

When a STOP instruction is encountered, execution of the current program cycle is terminated and the next execution cycle resumes at the first step of the program. If the STOP instruction is encountered on the last execution cycle, program execution is terminated, and any open serial or disk units are DETACHED and FCLOSEd. PROCEED or RETRY will not resume execution. (See EXECUTE for details on execution cycles.) When a PAUSE instruction is encountered, execution will be suspended. After a PAUSE, the system prompt will appear and Monitor Commands can be executed. This allows you to check the values of program variables and set system parameters. This is useful during program debugging. The monitor command PROCEED will resume execution of a program interrupted with the PAUSE command.

> **NOTE:** The PANIC monitor command halts program execution and robot motion immediately but leaves HIGH power on.

BRAKE, BREAK, DELAY

BRAKE aborts the current robot motion. This instruction can be issued from any task. Program execution is not suspended and the program (executing as task 0) will continue executing at the next instruction. BREAK suspends program execution (defeats forward processing) until the current robot motion is completed. This instruction can be executed only from a robot control program and is used when completion of the current robot motion must occur before execution of the next instruction. A DELAY instruction specifies the minimum delay between robot motions (not program instructions).

Additional Program Interrupt Instructions

You can specify a parameter in the instruction line for the I/O instructions ATTACH, READ, GETC, and WRITE that causes the program to suspend until the I/O request has been successfully completed.

Program Interrupt Example

The following example shows how the task and program priority scheme works. It also shows how the asynchronous and program interrupt instructions work within the priority scheme. The example makes the following simplifying assumptions:

- Task 1 runs in all time slices at priority 30
- Task 2 runs in all time slices at priority 20
- All system tasks are ignored
- All system interrupts are ignored

The illustration shows the time lines of executing programs. A solid line indicates a program is running, and a dotted line indicates a program is waiting. The Y axis shows the program priority. The X axis is divided into 16-millisecond major cycles. The example shows two tasks executing concurrently with REACT routines enabled for each task. Note how the LOCK instructions and triggering of the REACT routines change the program priority.

The sequence of events for the example is:

❶ Task 1 is running program “prog_a” at program priority 0. A reaction program based on signal 1003 is enabled at priority 5.

❷ Signal 1003 is asserted externally. The signal transition is not detected until the next major cycle.

❸ The signal 1003 transition is detected. The task 1 reaction program begins execution, interrupting “prog_a”.

❹ The task 1 reaction program reenables itself and completes by issuing a RETURN instruction. “prog_a” resumes execution in task 1.

❺ Task 1 “prog_a” issues a CLEAR.EVENT instruction followed by a WAIT.EVENT instruction to wait for its event flag to be set. Task 1 is suspended and task 2 resumes execution of “prog_b”. Task 2 has a reaction program based on signal 1010 enabled at priority 5.

❻ Task 2 “prog_b” issues a “LOCK 10” instruction to raise its program priority to level 10.

❼ Signal 1010 is asserted externally. The signal transition is not detected until the next major cycle.

❽ The signal 1010 transition is detected, and the task 2 reaction is triggered. However, since the reaction is at level 5 and the current program priority is 10, the reaction execution is deferred.

❾ Task 2 “prog_b” issues a “LOCK 0” instruction to lower its program priority to level 0. Since a level 5 reaction program is pending, it begins execution immediately and sets the program priority to 5.

❿ Signal 1003 is asserted externally. The signal transition is not detected until the next major cycle.

⓫ The signal 1003 transition is detected which triggers the task 1 reaction routine and also sets the task 1 event flag. Since task 1 has a higher priority (30) than task 2 (20), task 1 begins executing its reaction routine and task 2 is suspended.

⓬ The task 1 reaction routine completes by issuing a RETURN instruction. Control returns to “prog_a” in task 1.

⓭ Task 1 “prog_a” issues a CLEAR.EVENT instruction followed by a WAIT.EVENT instruction to wait for its event flag to be set. Task 1 is suspended and task 2 resumes execution of its reaction routine.

⓮ The task 2 reaction routine completes by issuing a RETURN instruction. Control returns to “prog_b” in task 2.

⓯ Task 2 “prog_b” issues a SET.EVENT 1 instruction, setting the event flag for task 1. Task 2 now issues a RELEASE program instruction to yield control of the CPU.

Since the task 1 event flag is now set, and its priority is higher then task 2, task 1 resumes execution and task 2 is suspended.

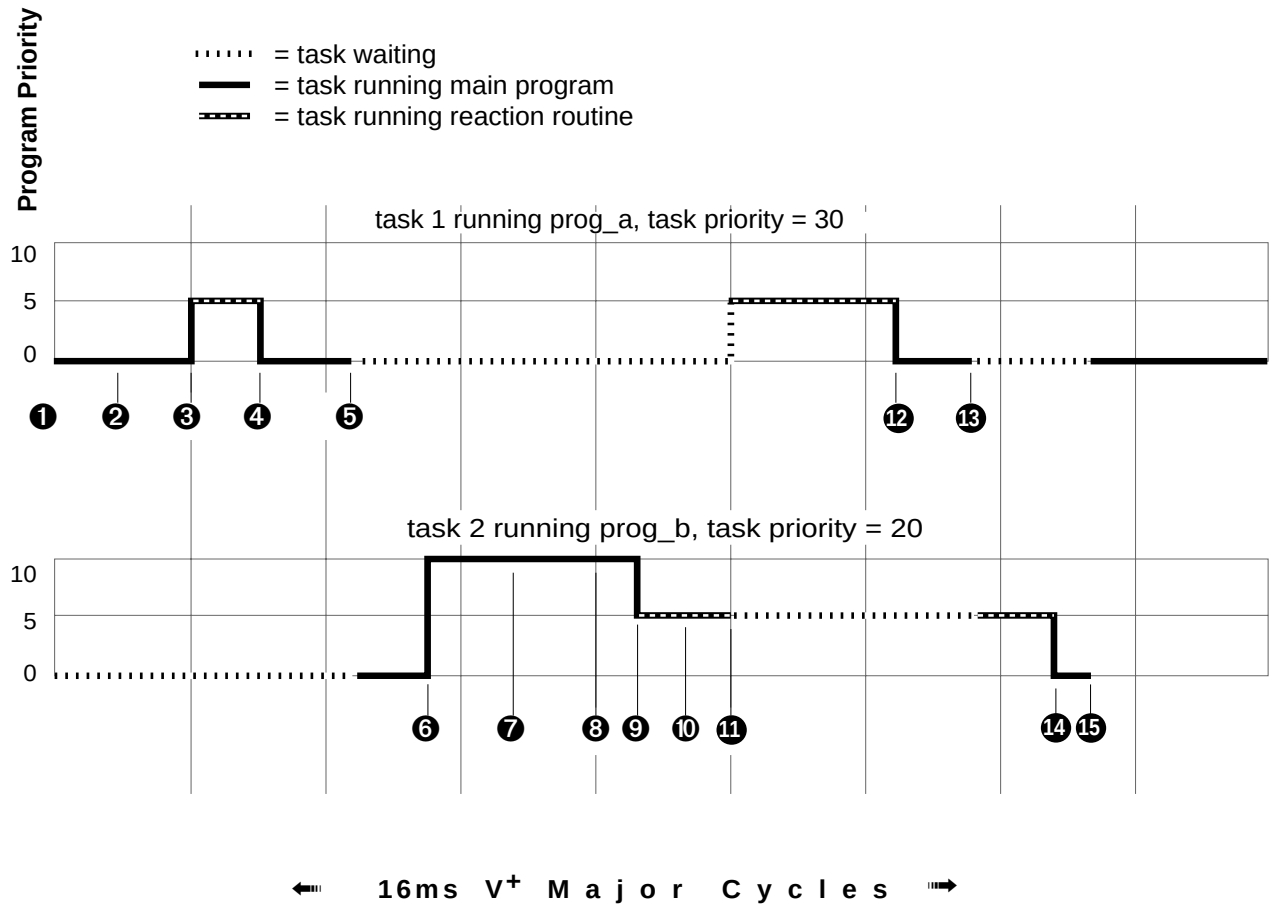

Figure 4-1. **Priority Example 2**

4.4 Logical (Boolean) Expressions

The next two sections discuss program control structures whose execution depends on an expression or variable that will take on a boolean value (a variable that is either true or false, or an expression that resolves to true or false). An expression can take into account any number of variables or digital input signals, so long as the final resolution of the expression is a boolean value. In V+, any number (real or integer) can satisfy this requirement. 0 is considered false; any non-zero number is considered true. There are four system constants, TRUE and ON that resolve to –1, and FALSE and OFF, that resolve to 0.

Examples of valid boolean expressions:

```
y > 32

NOT(y > 32)

x == 56

x AND y

(x AND y) OR (var1 < var2)

-1
```

See the section “Relational Operators” on page 73 for details on V+ relational operators.

4.5 Conditional Branching Instructions

Conditional branching instructions allow you to execute blocks of code based on the current values of program variables or expressions. V+ has three conditional branch instructions:

- IF...GOTO
- IF...THEN...ELSE
- CASE value OF

IF...GOTO

IF...GOTO behaves similarly to GOTO, but a condition can be attached to the branch. If the instruction:

```
IF logical_expression GOTO 100
```

is encountered, the branch to label 100 will occur only if “logical_expression” has a value of true.

IF...THEN...ELSE

The basic conditional instruction is the IF...THEN...ELSE clause. This instruction has two forms:

```
IF expression THEN
     code block (executed when expression is true)
END

IF expression THEN
     code block (executed when expression is true)
ELSE
     code block (executed when expression is false)
END
```

expression is any well-formed boolean expression (described above).

In the following example, if program execution reaches step 59 and “num_parts” is greater than 75, step 60 will be executed. Otherwise, execution will resume at step 62.

```
56          .
57      ;CALL "check_num" if "num_parts" is greater than 75
58
59          IF num_parts > 75 THEN
60               CALL check_num(num_parts)
61          END
62          .
```

In the following example, if program execution reaches step 37 with input signal 1033 “on” and “need_part” true, the program will execute steps 38 to 40 and resume at step 44. Otherwise, it will execute step 42 and resume at step 44.

```
32      .
33      ; If I/O signal 1033 is on and Boolean "need_part" is
34      ;    true, then pick up the part
35      ; else alert the operator.
36
37      IF SIG(1033) AND need_part THEN
38          MOVE loc1
39          CLOSEI
40          DEPART 50
41      ELSE
42          TYPE "Part not picked up."
43      END
44      .
```

CASE...VALUE OF

The IF...THEN...ELSE structure allows a program to take one of two different actions. The CASE structure will allow a program to take one of many different actions based on the value of a variable. The variable used must be a real or integer. The form of the CASE structure is:

```
CASE target OF
  VALUE list_of_values:
    code block (executed when target is in list_of_values)
  VALUE list_of_values:
    code block (executed when target is in list_of_values)
    ...
  ANY
      code block (executed when target not in any list_of_values)
END
```

target real value to match.

list_of_values list (separated by commas) of real values. If one of the values in the list equals **target**, the code following that value statement will be executed.

Example

```
65      ; Create a menu structure using a CASE statement
66
67  50      TYPE "1. Execute the program."
68          TYPE "2. Execute the programmer."
69          TYPE "3. Execute the computer."
70          PROMPT "Enter menu selection.", select
71
72          CASE select OF
73            VALUE 1:
74               CALL exec_program()
75            VALUE 2:
76               CALL exec_programmer()
77            VALUE 3:
78               CALL exec_computer()
79            ANY
80               PROMPT "Entry must be from 1 to 3", select
81               GOTO 50
82          END
83          .
```

If the above code is rewritten without an ANY statement, and a value other than 1, 2, or 3 is entered, the program will continue execution at step 83 without executing any program.

4.6 Looping Structures

In many cases, you will want the program to execute a block of code more than once. V+ has three looping structures that allow you to execute blocks of code a variable number of times. The three instructions are:

- FOR
- DO...UNTIL
- WHILE...DO

FOR

A FOR instruction creates an execution loop that will execute a given block of code a specified number of times. The basic form of a FOR loop is:

```
FOR index = start_val TO end_val STEP incr
     .
     code block
     .
END
```

index is a real variable that will keep track of the number of times the FOR loop has been executed. This variable is available for use within the loop.

start_val is a real expression for the starting value of the **index**.

end_val is a real expression for the ending value of the **index**. Execution of the loop will terminate when **index** reaches this value.

incr is a real expression indicating the amount **index** is to be incremented after each execution of the loop. The default value is 1.

Examples

```
88      .
89      ; Output even elements of array "$names" (up to index 32)
90
91           FOR i = 2 TO 32 STEP 2
92                TYPE $names[i]
93           END
94      .
        .
102     .
103     ; Output the values of the 2 dimensional array "values" in
104     ;    column and row form (10 rows by 10 columns)
105
106          FOR i = 1 TO 10
```

```
107               FOR j = 1 to 10
108                    TYPE values[i,j], /S
109               END
110               TYPE " ", /C1
111          END
112     .
```

A FOR loop can be made to “count backward” by entering a negative value for the step increment.

```
13      .
14      ; Count backward from 10 to 1
15
16           FOR i = 10 TO 1 STEP -1
17                TYPE i
18           END
19      .
```

Changing the value of **index** inside a FOR loop will cause the loop to behave improperly. To avoid problems with the **index**, make the **index** variable an auto variable and do not change the **index** from inside the FOR loop. Changes to the starting and ending variables will not affect the FOR loop once it is executing.

DO...UNTIL

DO...UNTIL is a looping structure that will execute a given block of code an indeterminate number of times. Termination of the loop depends on the boolean expression or variable that controls the loop becoming true. The boolean is tested after each execution of the code block—if the expression evaluates to true, the loop is not executed again. Since the expression is not evaluated until after the code block has been executed, the code block will always execute at least once. The form for this looping structure is:

```
DO
     .
     code block
     .
UNTIL expression
```

expression is any well-formed boolean expression (described above). This **expression** must eventually evaluate to true, or the loop will execute indefinitely (yes, the infamous infinite loop).

```
20          .
21      ; Output the numbers 1 to 100 to the screen
22
23          x = 1
24          DO
25               TYPE x
26               x = x + 1
27          UNTIL x > 100
28          .
```

Step 26 insures that “x” will reach a high enough value that the expression “x > 100” will become true.

```
43          .
44      ; Echo up to 15 characters to the screen. Stop when 15
45      ;    characters or the character "#" have been entered.
46
47          x = 1
48          DO
49               PROMPT "Enter a character: ", $ans
50               TYPE $ans
51               x = x + 1
52          UNTIL (x > 15) OR ($ans == "#")
53          .
```

In this code, either “x” reaching 15 or “#” being entered at the PROMPT instruction will terminate the loop. As long as the operator enters enough characters, the loop will terminate.

WHILE...DO

WHILE...DO is a looping structure similar to DO...UNTIL except the boolean expression is evaluated at the beginning of the loop instead of at the end. This means that if the condition indicated by the expression is true when the WHILE...DO instruction is encountered, the code within the loop will not be executed at all.

WHILE...DO loops are susceptible to infinite looping just as DO...UNTIL loops are. The expression controlling the loop must eventually evaluate to true for the loop to terminate. The form of the WHILE...DO looping structure is:

```
WHILE expression DO
     code block
END
```

expression is any well-formed boolean expression as described at the beginning of this section.

The following code shows a WHILE...DO loop being used to validate input. Since the boolean expression is tested before the loop is executed, the code within the loop will be executed only when the operator inputs an unacceptable value at step 23.

```
20          .
21      ; Loop until an operator inputs a value in the range 32-64
22
23          PROMPT "Enter a number in the range 32 to 64.", ans
24          WHILE (ans < 32) OR (ans > 64) DO
25               PROMPT "Number must be in the range 32-64.", ans
26          END
27          .
```

In the above code, an operator could enter a non-numeric value in which case the program would crash. A more robust strategy would be to use a string variable in the PROMPT instruction and then use the $DECODE and VAL functions to evaluate the input.

In the following code, if digital signal 1033 is “on” when step 69 is reached, the loop will not execute, and the program will continue at step 73. If digital signal 1032 is “off”, the loop will execute continually until the signal comes “on”.

```
65          .
66      ; Create a busy loop waiting for signal 1033 to turn "on"
67
68          WHILE NOT SIG(1033) DO
69
70               ;Wait for signal
71
72          END
73          .
```

4.7 Summary of Program Control Keywords

Table 4-1 summarizes the program control instructions.

Table 4-1. **Program Control Operations**

Keyword	Type	Function
ABORT	Program Instruction	Terminate execution of a control program.
CALL	Program Instruction	Suspend execution of the current program and continue execution with a new program (that is, a subroutine).
CALLS	Program Instruction	Suspend execution of the current program and continue execution with a new program (that is, a subroutine) specified with a string value.
CASE	Program Instruction	Initiate processing of a CASE structure by defining the value of interest.
CLEAR.EVENT	Program Instruction	Clear an event associated with the specified task.
CYCLE.END	Program Instruction	Terminate the specified control program the next time it executes a STOP program instruction (or its equivalent). Suspend processing of an application program or command program until a program completes execution.
DO	Program Instruction	Introduce a DO program structure.
EXECUTE	Program Instruction	Begin execution of a control program.
EXECUTE	Monitor Command	Begin execution of a control program.
EXIT	Program Instruction	Exit a FOR, DO, or WHILE control structure.
FOR	Program Instruction	Execute a group of program instructions a certain number of times.
GET.EVENT	Real-Valued Function	Return events that are set for the specified task.
GOTO	Program Instruction	Perform an unconditional branch to the program step identified by the given label.
HALT	Program Instruction	Stop program execution and do not allow the program to be resumed.
IF...GOTO	Program Instruction	Branch to the specified label if the value of a logical expression is TRUE (nonzero).

Table 4-1. **Program Control Operations** (Continued)

Keyword	Type	Function
IF...THEN	Program Instruction	Conditionally execute a group of instructions (or one of two groups) depending on the result of a logical expression.
INT.EVENT	Program Instruction	Send a SET.EVENT instruction to the current task if an interrupt occurs on a specified VME bus vector.
LOCK	Program Instruction	Set the program reaction lock-out priority to the value given.
MCS	Program Instruction	Invoke a monitor command from a control program.
NEXT	Program Instruction	Break a FOR, DO, or WHILE structure and start the next iteration of the control structure.
PAUSE	Program Instruction	Stop program execution but allow the program to be resumed.
PRIORITY	Real-Valued Function	Return the current reaction lock-out priority for the program.
REACT REACTI	Program Instruction	Initiate continuous monitoring of a specified digital signal and automatically trigger a subroutine call if the signal transitions properly.
REACTE	Program Instruction	Initiate the “monitoring” of errors that occur during execution of the current program task.
RELEASE	Program Instruction	Allow the next available program task to run.
RETRY	System Switch	Control whether the PROGRAM START button causes a program to resume.
RETURN	Program Instruction	Terminate execution of the current subroutine and resume execution of the last-suspended program at the step following the CALL or CALLS instruction that caused the subroutine to be invoked.
RETURNE	Program Instruction	Terminate execution of an error reaction subroutine and resume execution of the last-suspended program at the step following the instruction that caused the subroutine to be invoked.
RUNSIG	Program Instruction	Turn “on” (or “off”) the specified digital signal as long as execution of the invoking program task continues.
SET.EVENT	Program Instruction	Set an event associated with the specified task.
STOP	Program Instruction	Terminate execution of the current program cycle.

Table 4-1. **Program Control Operations** (Continued)

Keyword	Type	Function
WAIT	Program Instruction	Put the program into a "wait loop" until the condition is TRUE.
WAIT.EVENT	Program Instruction	Suspend program execution until a specified event has occurred, or until a specified amount of time has elapsed.
WHILE	Program Instruction	Initiate processing of a WHILE structure if the condition is TRUE, or skipping of the WHILE structure if the condition is initially FALSE.

4.8 Controlling Programs in Multiple CPU Systems

V+ systems equipped with multiple CPUs and optional V+ Extensions can run multiple copies of V+. Keep the following considerations in mind when running multiple V+ systems:

- An A-Series system is required.
- The second, third, etc. V+ copies will be displayed in separate windows on the monitor. These windows are labeled "Monitor_2", "Monitor_3", etc. The system switch MONITORS must be enabled before these windows can be displayed. The CPU number is determined by the board address switch (see the *Adept MV Controller User's Guide*).
- ALL V+ copies share the same digital input, output, and soft signals. Global variables are not shared.
- The IOGET_ and IOPUT_ instructions can be used to share data between V+ copies via an 8 KB reserved section of shared memory on each board. Acceptable address values are 0 to hexadecimal value 1FFF (decimal value 0 to 8191). This memory area is used only for communication between V+ application programs, and is not used for any other purpose. (It is not possible to access the rest of the processor memory map.)
- The IOTAS() function can be used to interlock access to user data structures.
- The addresses are based on single-byte (8-bit) values. For example, if you write a 32-bit value to an address it will occupy four address spaces (the address that you specify, and the next three addresses).
- If you read a value from a location using a format different than the format that was used to write to that location, you will also get an invalid value but you will not get an error message. (For example, if you write using IOPUTF and read using IOPUTL, your data will be invalid.)

NOTE: V+ does not enforce any memory protection schemes for use of the application shared-memory area. It is the user's responsibility to keep track of memory usage. If you are using application or utility programs written by someone else (for example, Adept AIM VisionWare or AIM MotionWare), you should read the documentation provided with that software to check that it does not conflict with your usage of the shared area.
AIM users should note that Adept plans to assign application shared-memory starting from the top (hexadecimal value 1FFF) and working down. Users should therefore start at the bottom (value 0) and work up. AIM 2.3 does not use any of the shared area, but future versions are expected to use approximately 2K of the shared area (from hexadecimal value 1FFF down to about 1800).

- In general, robot control and system configuration changes must be performed from CPU #1. CPUs other than #1 always start up with the stand-alone control module. No belts or kinematic modules are loaded.
- Multiple CPUs can each execute their own autostart routines. CPU #1 will load the normal AUTO file and execute the program "auto", CPU #2 will load the file "AUTO02.V2" and execute the program "auto02", CPU #3 will load "AUTO03.V2" and execute the program "auto03", etc.

5 Functions

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5.1 Using Functions

V+ provides you with a wide variety of predefined functions for performing string, mathematical, and general system parameter manipulation. Functions generally require you to provide them with data, and they return a value based on a specific operation on that data. Functions can be used anywhere a value or expression would be used.

Variable Assignment Using Functions

The instruction:

```
$curr_time = $TIME()
```

will put the current system time into the variable "$curr_time". This is an example of a function that does not require any input data. The instruction:

```
var_root = SQRT(x)
```

will put the square root of the value "x" into "var_root". "x" will not be changed by the function.

Functions Used in Expressions

A function can be used wherever an expression can be used (as long as the data type returned by the function is the correct type). The instruction:

```
IF LEN($some_string) > 12 THEN
```

will result in the boolean expression being true if the string "$some_string" has more than 12 characters. The instruction:

```
array_var = some_array[VAL($x)]
```

will result in "array_var" having the same value as the array cell "$x". (VAL converts a string to a real.)

Functions as Arguments to a Function

In most cases, the values passed to a function are not changed. This not only protects the variables you use as arguments to a function, but allows you to use a function as an argument to a function (so long as the data type returned is the type expected by the function). For example:

```
i = SQRT(SQR(x))
```

will result in "i" having the absolute value of x. (i = Ð(-2^2) = 2).

5.2 String-Related Functions

The value returned from a string function may be another string or a numeric value.

Table 5-1. **String-Related Functions**

Keyword	Function
ASC	Return a single character value from within a string.
$CHR	Return a one-character string having a given value.
DBLB	Return the value of eight bytes of a string interpreted as an IEEE double-precision floating-point number.
$DBLB	Return an 8-byte string containing the binary representation of a real value in double-precision IEEE floating-point format.
$DECODE	Extract part of a string as delimited by given “break” characters.
$ENCODE	Return a string created from output specifications. The string produced is similar to the output of a TYPE instruction.
FLTB	Return the value of four bytes of a string interpreted as an IEEE single-precision floating-point number.
$FLTB	Return a 4-byte string containing the binary representation of a real value in single-precision IEEE floating-point format.
$INTB	Return a 2-byte string containing the binary representation of a 16-bit integer.
LEN	Return the number of characters in the given string.
LNGB	Return the value of four bytes of a string interpreted as a signed 32-bit binary integer.
$LNGB	Return a 4-byte string containing the binary representation of a 32-bit integer.
$MID	Return a substring of the specified string.
PACK	Replace a substring within an array of (128-character) string variables, or within a (non-array) string variable.
POS	Return the starting character position of a substring in a string.
$TRANSB	Return a 48-byte string containing the binary representation of a transformation value.
$TRUNCATE	Return all characters in the input string until an ASCII NUL (or the end of the string) is encountered.
$UNPACK	Return a substring from an array of 128-character string variables.
VAL	Return the real value represented by the characters in the input string.

Examples of String Functions

The instruction:

```
TYPE $ERROR(-504)
```

will output the text "*Unexpected end of file*" to the screen.

The instructions:

```
$message = "The length of this line is: "
TYPE $ENCODE($message, /I0, LEN($message)+14), " characters."
```

will output the message "The length of this line is: 42 characters."

5.3 Location, Motion, and External Encoder Functions

V+ provides numerous functions for manipulating and converting location variables. See Chapter 7 for details on motion processing and a table that includes all location related functions. See Appendix B for details on the external encoders.

Examples of Location Functions

The instruction:

```
rotation = RZ(HERE)
```

will place the value of the current rotation about the Z axis in the variable "rotation".

The instruction:

```
dist = DISTANCE(HERE, DEST)
```

will place the distance between the motion device's current location and its destination (the value of the next motion instruction).

The instructions:

```
IF INRANGE(loc_1) == 0 THEN
     IF SPEED(2) > 50 THEN
          SPEED 50
     END
     MOVE(loc_1)
END
```

will ensure "loc_1" is reachable and then move the motion device to that location at a program speed not exceeding 50.

5.4 Numeric Value Functions

The functions listed in Table 5-2 provide trigonometric, statistical, and data-type conversion operations. See Chapter 3 for additional details on arithmetic processing.

Table 5-2. **Numeric Value Functions**

Keyword	Function
ABS	Return absolute value.
ATAN2	Return the size of the angle (in degrees) that has its trigonometric tangent equal to value_1 / value_2.
BCD	Convert a real value to Binary Coded Decimal (BCD) format.
COS	Return the trigonometric cosine of a given angle.
DCB	Convert BCD digits into an equivalent integer value.
FRACT	Return the fractional part of the argument.
INT	Return the integer part of the value.
INTB	Return the value of two bytes of a string interpreted as a signed 16-bit binary integer.
MAX	Return the maximum value contained in the list of values.
MIN	Return the minimum value contained in the list of values.
OUTSIDE	Test a value to see if it is outside a specified range.
PI	Return the value of the mathematical constant pi (3.141593).
RANDOM	Return a pseudorandom number.
SIGN	Return the value 1, with the sign of the “value” parameter.
SIN	Return the trigonometric sine of a given angle.
SQR	Return the square of the parameter.
SQRT	Return the square root of the parameter.

Examples of Arithmetic Functions

The instructions:

```
$a = "16"
x = SQRT(VAL($a))
```

will result in “x” having a value of 4.

The instruction:

```
x = INT(RANDOM*10)
```

will create a pseudorandom number between 0 and 10.

5.5 Logical Functions

The functions listed in Table 5-3 return boolean values. These functions require no arguments and essentially operate as system constants.

Table 5-3. **Logical Functions**

Keyword	Function
FALSE	Return the value used by V+ to represent a logical false result.
OFF	Return the value used by V+ to represent a logical false result.
ON	Return the value used by V+ to represent a logical true result.
TRUE	Return the value used by V+ to represent a logical true result.

5.6 System Control Functions

The functions listed in Table 5-4 return information about the system and system parameters.

Table 5-4. **System Control Functions**

Keyword	Function
DEFINED	Determine whether a variable has been defined.
ERROR	Return the error number of a recent error that caused program execution to stop or caused a REACTE reaction.
$ERROR	Return the error message associated with the given error code.
FREE	Return the amount of unused free memory storage space.
GET.EVENT	Return events that are set for the specified task.
ID	Return values that identify the configuration of the current system.
$ID	Return the system creation date and edit / revision information.
LAST	Return the highest index used for an array (dimension).
PARAMETER	Return the current setting of the named system parameter.
PRIORITY	Return the current reaction lock-out priority for the program.
SELECT	Return the unit number that is currently selected by the current task for the device named.
STATUS	Return status information for an application program.
SWITCH	Return an indication of the setting of a system switch.

Table 5-4. **System Control Functions** (Continued)

Keyword	Function
TAS	Return the current value of a real-valued variable and assign it a new value. The two actions are done "indivisibly" so no other program task can modify the variable at the same time.
TASK	Return information about a program execution task.
TIME	Return an integer value representing either the date or the time specified in the given string parameter.
$TIME	Return a string value containing either the current system date and time or the specified date and time.
TIMER	Return the current time value (in seconds) of the specified system timer.
TPS	Return the number of ticks of the system clock that occur per second (Ticks Per Second).

Example of System Control Functions

The instruction:

```
IF (TIMER(2) > 100) AND (DEFINED(loc_1)) THEN
     MOVE loc_1
END
```

would execute the MOVE instruction only if timer(2) had a value greater than 100 and the variable "loc_1" had been defined.

5.7 I/O Functions

V+ provides numerous functions for reading and writing data to and from various I/O devices. See Chapter 8 for a table that includes all I/O functions as well as complete details on I/O processing.

Examples of I/O Functions

The instructions:

```
WHILE IOSTAT(5) > 0 DO
     READ(5) $txt
     TYPE $txt
END
```

will output the characters from a disk file open on logical unit 5.

6 Switches and Parameters

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6.1 Introduction

System parameters determine certain operating characteristics of the V+ system. These parameters have numeric values that can be changed from the command line or from within a program to suit particular system configurations and needs. The various parameters are described in this chapter along with the operations for displaying and changing their values.

System switches are similar to system parameters in that they control the operating behavior of the V+ system. Switches differ from parameters, however, in that they do not have numeric values. Switches can be set to either “enabled” or “disabled,” which can be thought of as “on” and “off,” respectively.

All the basic system switches are described in this chapter. The monitor commands and program instructions that can be used to display and change their settings are also presented.

6.2 Parameters

See the *V+ Language Reference Guide* for more detailed descriptions of the keywords discussed here.

Whenever a system parameter name is used, it can be abbreviated to the minimum length required to identify the parameter. For example, the “HAND.TIME” parameter can be abbreviated to “H”, since no other parameter name begins with “H”.

Viewing Parameters

To see the state of a single parameter, use the PARAMETER monitor command:

```
PARAMETER parameter_name
```

If “parameter_name” is omitted, the value of all parameters is displayed.

To retrieve the value of a parameter from within a program, use the PARAMETER function. The instruction:

```
TYPE "HAND.TIME parameter =", PARAMETER(HAND.TIME)
```

will display the current setting of the hand-delay parameter in the monitor window.

The PARAMETER function can be used in any expression to include the value of a parameter. For example, the following program statement will increase the delay for hand actuation:

```
PARAMETER HAND.TIME = PARAMETER(HAND.TIME) + 0.15
```

Note that the left-hand occurrence of “PARAMETER” is the instruction name and the right-hand occurrence is the function name.

Setting Parameters

To set a parameter from the command line, use the PARAMETER monitor command. The instruction:

```
PARAMETER SCREEN.TIMEOUT = 10
```

sets the screen blanking time to 10 seconds.

To set a parameter in a program, use the PARAMETER program instruction. The instruction:

```
PARAMETER NOT.CALIBRATED = 1
```

asserts the "not calibrated" state for robot 1.

In systems with AdeptVision VME, some parameters are organized as arrays and must be accessed by specifying an array index. (See the *AdeptVision Reference Guide* for more information on such parameters.)

Summary of Basic System Parameters

System parameters are set to defaults when the V+ system is initialized. The default values are indicated with each parameter description below. The settings of the parameter values are not affected by the ZERO command.

If your robot system includes optional enhancements (such as vision), you will have other system parameters available. Consult the documentation for the options for details. The basic system parameters are:

Table 6-1. **Basic System Parameters**

Parameter	Use	Default	Min	Max
BELT.MODE	Controls the operation of the conveyor tracking feature of the V+ system.	0	0	14
HAND.TIME	Determines the duration of the motion delay that occurs during processing of OPENI, CLOSEI, and RELAXI instructions. The value for this parameter is interpreted as the number of seconds to delay. Due to the way in which V+ generates its time delays, the HAND.TIME parameter is internally rounded to the nearest multiple of 0.016 seconds.	0.05	0	1E18
KERMIT.RETRY	Sets the number of times Kermit will attempt to transfer a data packet before quitting with an error.	15	1	1000
KERMIT.TIMEOUT	Time, in seconds, that Kermit will wait before retrying the transfer of a data packet.	8	1	95

Table 6-1. **Basic System Parameters** (Continued)

Parameter	Use	De-fault	Min	Max
NOT.CALIBRATED	Represents the calibration status of the robot(s) controlled by the V+ system.	7	0	7
SCREEN.TIMEOUT	Controls automatic blanking of the graphics monitor on the A-Series controller.	0	0	16383
TERMINAL	This parameter determines how the V+ monitor will interact with the A-series system terminal. The acceptable values are 0 through 4, and they have the interpretations shown in the following table.	4	0	4

The default value for TERMINAL is changed with the utility "CONFIG_C.V2" on the Adept Utility Disk. See the *Instructions for Adept Utility Programs.*

A-Series System Terminal Settings

Parameter Value	Terminal Type	Treatment of DEL & BS	Cursor-up Command
0	TTY	\<echo>\	None
1	CRT	Erase	<VT>
2	CRT	Erase	<SUB>
3	CRT	Erase	<FF>
4	CRT	Erase	<ESC>M

6.3 Switches

System switches govern various features of the V+ system. The switches are described below. See the *V+ Language Reference Guide* and the *V+ Operating System Reference Guide* for more detailed descriptions of the keywords discussed here.

As with system parameters, the names of system switches can be abbreviated to the minimum length required to identify the switch.

Viewing Switch Settings

The SWITCH monitor command displays the setting of one or more system switches:

```
SWITCH switch_name, ..., switch_name
```

If no switches are specified, the settings of all switches are displayed.

Within programs, the SWITCH real-valued function returns the status of a switch. The instruction:

```
SWITCH(switch_name)
```

returns TRUE (–1.0) if the switch is enabled or FALSE (0.0) if the switch is disabled.

In systems with AdeptVision VME, some switches are organized as arrays and may be accessed by specifying the array index. (See the *AdeptVision Reference Guide* for more information on such switches.)

Setting Switches

The ENABLE and DISABLE monitor commands / program instructions control the setting of system switches. The instruction:

```
ENABLE BELT
```

will enable the BELT switch. The instruction:

```
DISABLE BELT, CP
```

will disable the CP and BELT switches. Multiple switches can be specified for either instruction.

Switches can also be set with the SWITCH program instruction. Its syntax is:

```
SWITCH switch_name = value
```

This instruction differs from the ENABLE and DISABLE instructions in that the SWITCH instruction enables or disables a switch depending on the value on the right-hand side of the equal sign. This allows you to set switches based on a variable or expression. The switch is enabled if the value is TRUE (nonzero), and disabled if the value is FALSE (zero). The instruction:

```
SWITCH CP = SIG(1001)
```

will enable the continuous path (CP) switch if input signal 1001 is on.

Summary of Basic System Switches

The default switch settings at system power-up are given in the switch descriptions below. (The switch settings are not affected by the ZERO command.)

Optional enhancements to your V+ system may include additional system switches. If so, they are described in the documentation for the options. The system switches are:

Table 6-2. **Basic System Switches**

Switch	Use
BELT	Used to turn on the conveyor tracking features of V+ (if the option is installed). This switch must be enabled before any of the special conveyor tracking instructions can be executed. When BELT is disabled, the conveyor tracking software has a minimal impact on the overall performance of the system. Default is disabled.
CP	Enable / disable continuous-path motion processing (see page 129). Default is enabled.
DRY.RUN	Enable / disable sending of motion commands to the robot. Enable this switch to test programs for proper logical flow and correct external communication without having to worry about the robot running into something. (Also see the TRACE switch, which is useful during program checkout.) The manual control pendant can still be used to move the robot when DRY.RUN is enabled. Default is disabled.
FORCE	Controls whether the (optional) stop-on-force feature of the V+ system is active. Default is disabled.
INTERACTIVE	Suppresses display of various messages on the system terminal. In particular, when the INTERACTIVE switch is disabled, V+ does not ask for confirmation before performing certain operations, and does not output the text of error messages. This switch is usually disabled when the system is being controlled by a supervisory computer to relieve the computer from having to process the text of messages. Default is enabled.
MCP.MESSAGES	Controls how system error messages are handled when the controller keyswitch is **not** in the “PENDANT” position. Default is disabled.
MCS.MESSAGES	Controls whether monitor commands executed with the MCS instruction will have their output displayed on the terminal. Default is disabled.

Table 6-2. **Basic System Switches** (Continued)

Switch	Use
MESSAGES	Controls whether output from TYPE instructions will be displayed on the terminal. Default is enabled.
NETWORK	Controls whether the V+ system communicates with the external communication port. Until this switch is enabled, V+ ignores the existence of the port. Default is disabled.
POWER	Tracks the status of Robot Power; this switch is automatically enabled whenever Robot Power is turned on. This switch can also be used to turn Robot Power on or off—enabling the switch turns on Robot Power and disabling the switch turns off Robot Power. Default is disabled.
	WARNING: WE RECOMMEND THAT YOU DO NOT TURN ON ROBOT POWER FROM WITHIN A PROGRAM since the robot can be activated without direct operator action. Turning on Robot Power from the terminal can be hazardous if the operator does not have a clear view of the robot workspace.
RETRY	Controls whether the PROGRAM START button on the front panel of the system controller causes a program to resume. Default is disabled.
ROBOT	This is an array of switches that control whether or not the system should access robots normally controlled by the system. Default is disabled.
SET.SPEED	Enable / disable the ability to set the monitor speed from the manual control pendant. Default is enabled.
TRACE	Enable / disable a special mode of program execution in which each program step is displayed on the system terminal before it is executed. This is useful during program development for checking the logical flow of execution (also see the DRY.RUN switch). Default is disabled.
UPPER	Determines whether comparisons of string values will consider lowercase letters the same as uppercase letters. When this switch is enabled, all lowercase letters are considered as though they are uppercase. Default is enabled.

7 Motion Control Operations

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7.1 Introduction

A primary focus of the V+ language is to drive motion devices. This chapter discusses the language elements that generate controller output to move a motion device from one location to another. Before we introduce the V+ motion instructions, we should examine the V+ location variables and see how they relate to the space the motion device operates in.

7.2 Location Variables

Locations can be specified in two ways in V+, transformations and precision points.

A transformation is a set of six components that uniquely identifies a location in Cartesian space and the orientation of the motion device end-of-arm tooling at that location. A transformation can also represent the location of an arbitrary local reference frame.

A precision point includes an element for each “joint” in the motion device. Rotational joint values are measured in degrees; translational joint values are measured in millimeters. These values are absolute with respect the motion device’s home sensors and cannot be made relative to other locations or coordinate frames.

Coordinate Systems

Figure 7-1 shows the world coordinate system for an Adept SCARA robot and an Adept Cartesian robot. Ultimately, all transformations are based on a world coordinate system. The V+ language contains several instructions for creating local reference frames, building relative transformations, and changing the origin of the base (world) coordinate frame. Therefore, an individual transformation may be relative to another transformation, a local reference frame, or an altered base reference frame.

Different robots and motion devices will designate different locations as the origin of the world coordinate system. See the user’s guide for Adept robots or the device module documentation for AdeptMotion VME systems to determine the origin and orientation of the world coordinate frame.

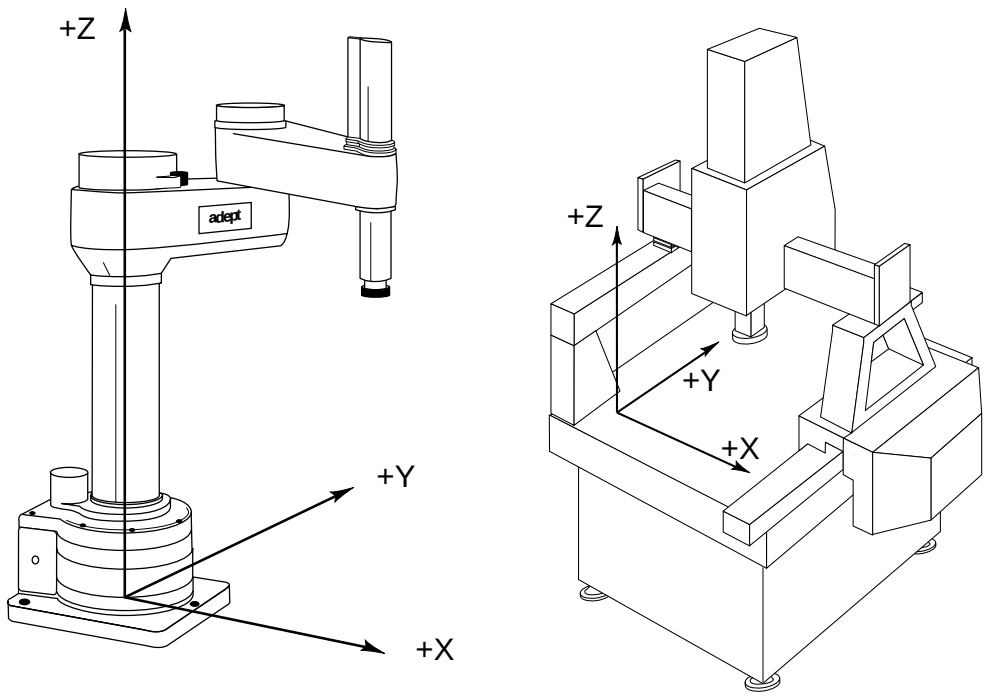

Figure 7-1. **Adept Robot Cartesian Space**

Transformations

The first three components of a transformation variable are the values for the points on the X, Y, and Z axes. In an Adept SCARA robot, the origin of this Cartesian space is the base of the robot. The Z axis points straight up through the middle of the robot column. The X axis points straight out, and the Y axis runs left to right as you face the robot. The first robot in Figure 7-1 shows the orientation of the Cartesian space for an Adept SCARA robot. The location of the world coordinate system for other robots and motion devices depends on the kinematic model of the motion device. For example, the second robot in Figure 7-1 shows the world coordinate frame for a robot built on the Cartesian coordinate model. See the kinematic device module documents for your particular motion device.

When a transformation is defined, a local reference frame is created at the X, Y, Z location with all three local frame axes parallel to the world coordinate frame. Figure 7-2 shows the first part of a transformation. This transformation has the value X = 30, Y = 100, Z = 125, yaw = 0, pitch = 0, and roll = 0.

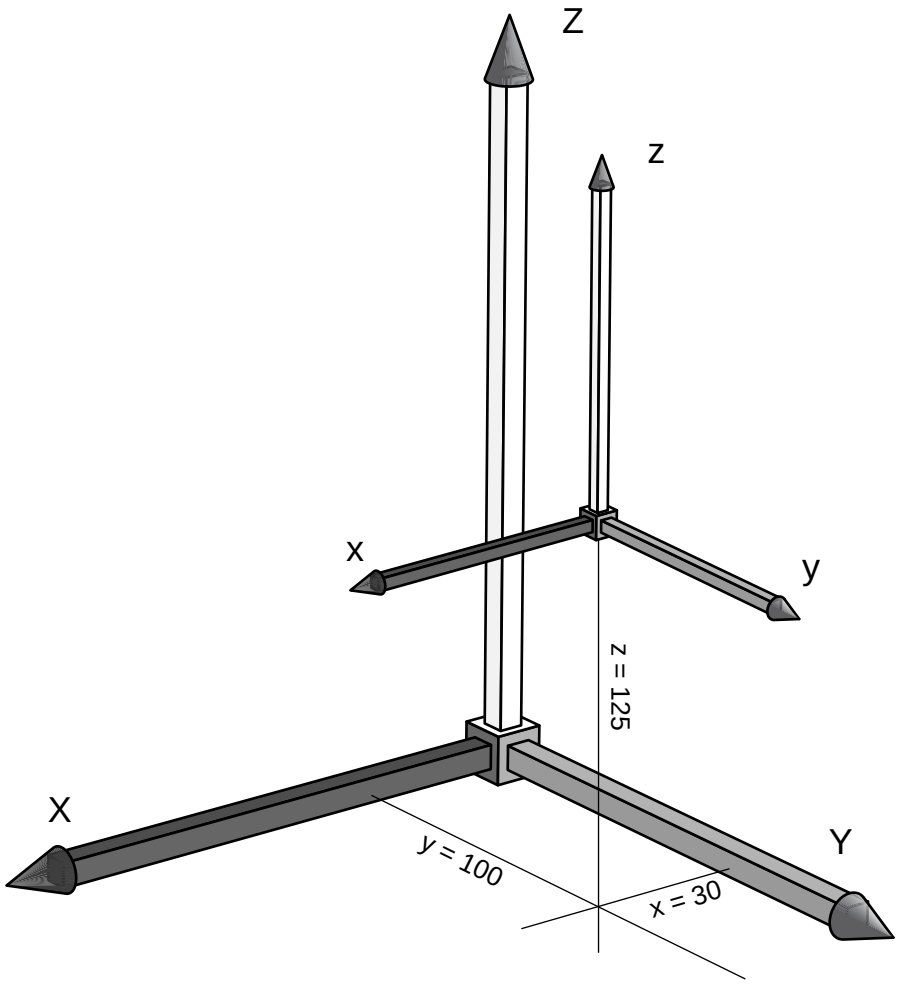

Figure 7-2**. XYZ Elements of a Transformation**

The second three components of a transformation variable specify the orientation of the end-of-arm tooling. These three components are yaw, pitch, and roll. These elements are figured as ZYZ' Euler values. Figures 7-3 through 7-5 demonstrate how these values are interpreted.

Yaw

Yaw is a rotation about the local reference frame Z axis. This rotation is not about the primary reference frame Z axis, but is centered at the origin of the local frame of reference. Figure 7-3 shows the yaw axis with a rotation of 30°. Note that it is parallel to the primary reference frame Z axis but may be centered at any point in that space. In this example, the yaw value is 30°, resulting in a transformation with the value (X = 30, Y = 100, Z = 125, yaw = 30, pitch = 0, and roll = 0).

When you are using a robot, the local frame of reference defined by the XYZ components is located at the end of the robot tool flange. (This local reference frame is referred to as the "tool" coordinate system.) In Figure 7-3, the large Cartesian space represents a world coordinate system. The small Cartesian space represents a local tool coordinate system (that would be centered at the motion device tooling flange).

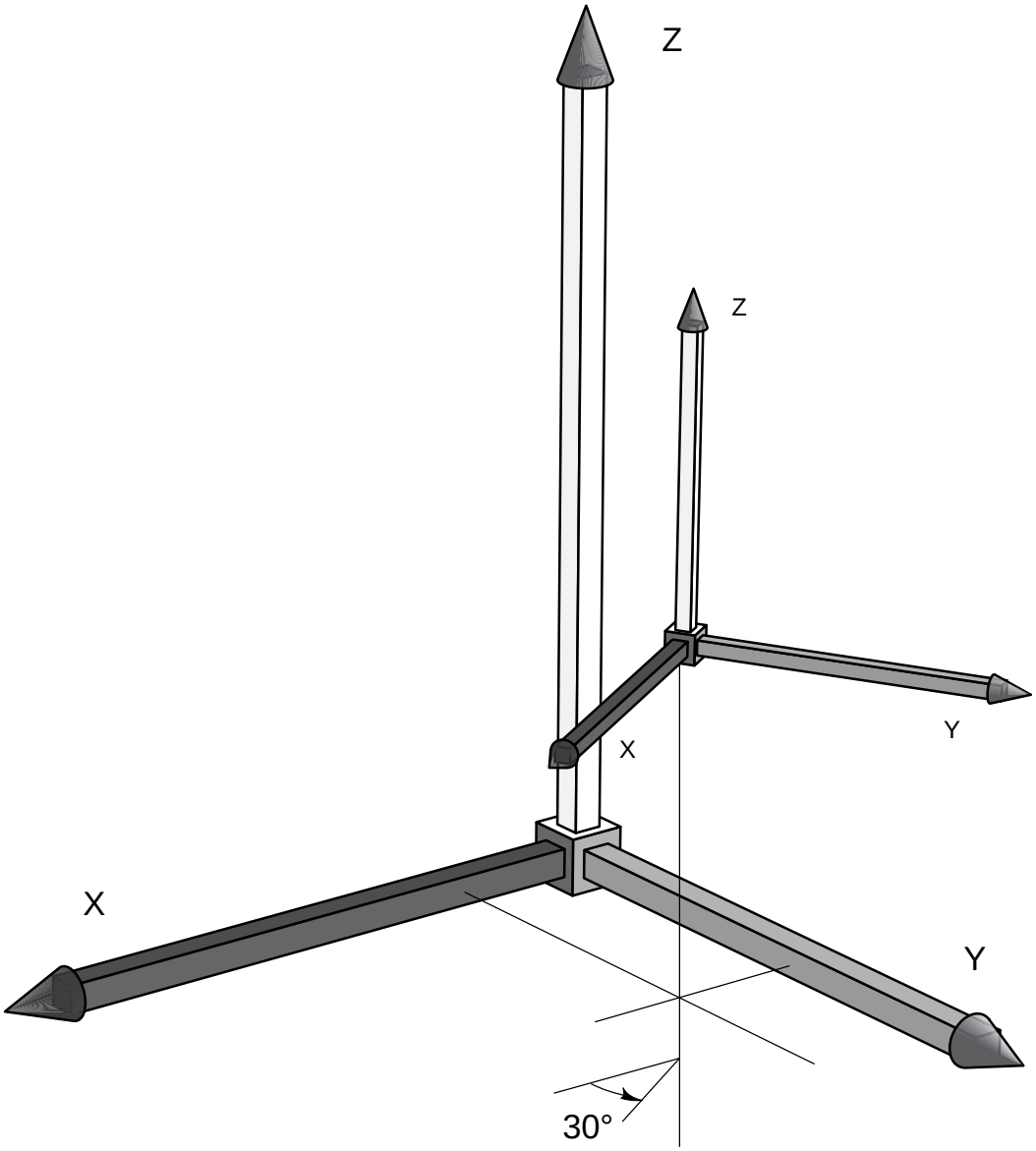

Figure 7-3. **Yaw**

Pitch

Pitch is defined as a rotation about the local reference frame Y axis, after yaw has been applied. Figure 7-4 shows the local reference frame with a yaw of 30° and a pitch of 40°.

For example, deflection of a “wrist” joint is reflected in the pitch component. The movement of a fifth axis on a SCARA robot is reflected in the pitch component. In this example, the motion device end of arm tooling has a pitch of 40°, resulting in a transformation with the value (X = 30, Y = 100, Z = 125, yaw = 30, pitch = 40, and roll = 0). This location can be reached only by a mechanism with a fifth axis. Pitch is represented as ±180°, not as 360° of rotation. Thus, a positive rotation of 190° is shown as –170°.

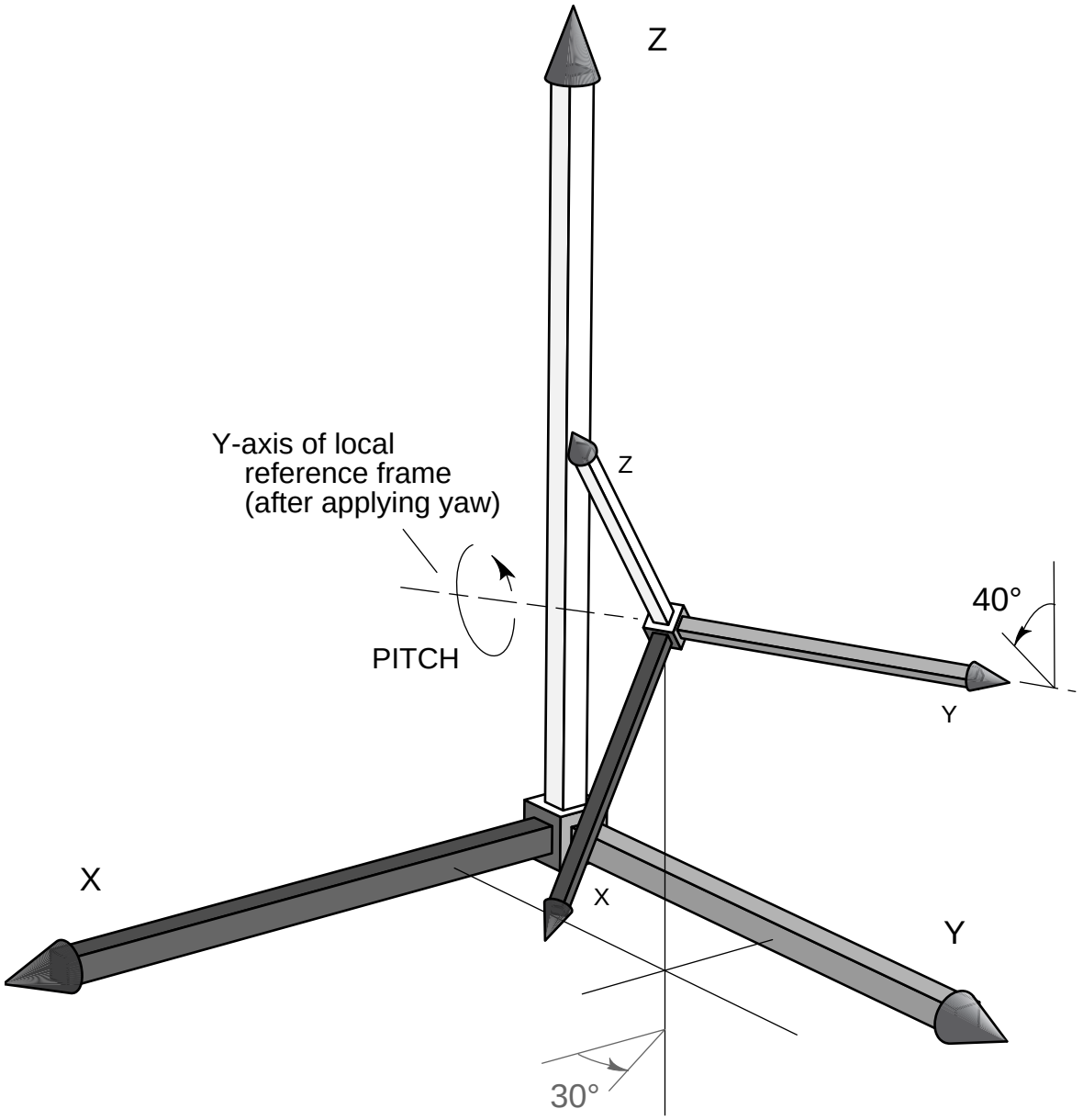

Figure 7-4. **Pitch**

Roll

Roll is defined as a rotation about the Z axis of the local reference frame after yaw and pitch have been applied. Figure 7-5 shows a local reference frame in the primary robot Cartesian space and the direction roll would take within that space. In this example the transformation has a value of X = 30, Y = 100, Z = 125, yaw = 30, pitch = 40, and roll = 20. This location can be reached only by a mechanism with fifth and sixth axes.

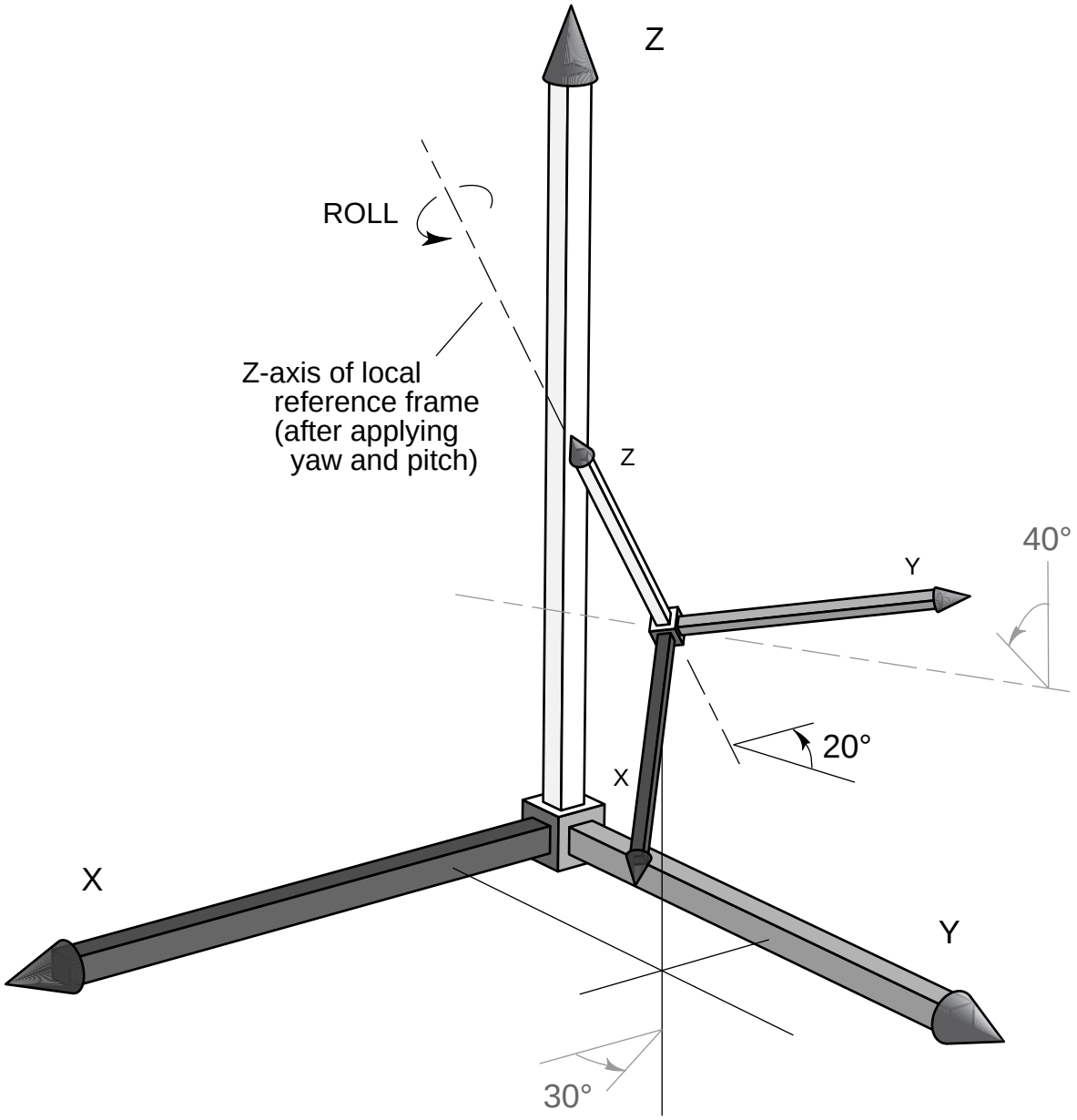

Figure 7-5. **Roll**

Special Situations

When the Z axes of the local and primary reference frames are parallel, roll and yaw produce the same motion in the same plane, although the two motions may be in different directions. This is always the case with a four-axis SCARA robot. The system automatically reflects rotation of the quill in the roll component of a transformation variable, and the yaw component is forced to 0°. In a SCARA robot equipped with a fifth axis, rotation of the quill is reflected in the yaw component and motion of a rotating end effector (sixth axis) is reflected in the roll component.

Notice in Figure 7-2 that the local reference frame points straight up. This corresponds to a situation where the end of arm tooling points straight back along the third axis. In a mechanism not equipped with a 360° wrist, this is an impossible position. For a four-axis SCARA, this component must point straight down (pitch = 180°). For a mechanism with a fifth axis, this component must be within the range of motion of the fifth axis.

> **NOTE:** Remember, when thinking about a transformation, the rules of ZYZ' Euler angles require that the orientation components be applied in order after the local reference frame has been defined. After calculating the Cartesian components and placing a local reference frame with x, y, and z axes parallel to the primary reference frame X, Y, and Z axes, the orientation components are applied in a strict order—yaw is applied first, then pitch, and finally roll.

7.3 Creating and Altering Location Variables

Creating Location Variables

The most straightforward method of creating a location variable is to place the robot or motion device at a location and enter the monitor command:

```
HERE loc_name
```

If you have the optional Adept manual control pendant, you can use the pendant and the TEACH instruction to create location variables.

Transformations vs. Precision Points

A location can be specified using either the six components described in the previous section, or by specifying the state the robot joints would be in when a location is reached. The former method results in a “transformation” variable. Transformations are the most flexible and efficient location variables.

Precision points record the joint values of each joint in the motion device. Precision points may be more accurate, and they are the only way of extracting joint information that will allow you to move an individual joint. Precision points are identified by a leading pound sign (#). The command:

```
HERE #pick
```

will create the precision point “#pick” equal to the current robot joint values.

Modifying Location Variables

The individual components of an existing transformation or precision point can be edited with the POINT monitor command:

```
POINT loc_name
```

will display the transformation components of “loc_name” and allow you to edit them. If “loc_name” is not defined, a null transformation will be displayed for editing.

A location variable can be duplicated using the POINT monitor command or SET program instruction. The monitor command:

```
POINT loc_name = loc_value
```

and the program instruction:

```
SET loc_name = loc_value
```

will both result in the variable “loc_name” being given the value of “loc_value”. The POINT monitor command also allows you to edit “loc_name” after it had been assigned the value of “loc_value”.

The following functions return transformation values:

TRANS	Create a location by specifying individual components of a transformation. A value can be specified for each component.
SHIFT	Alter the Cartesian components of an existing transformation.

The POINT and SET operations can be used in conjunction with the transformation functions SHIFT and TRANS to create location variables based on specific modifications of existing variables.

```
SET loc_name = SHIFT(loc_value BY 5, 5, 5)
```

will create the location variable “loc_name”. The location of “loc_name” will be shifted 5 mm in the positive X, Y, and Z directions from “loc_value”.

Relative Transformations

Relative transformations allow you to make one location relative to another and to build local reference frames that transformations can be relative to. For example, you may be building an assembly whose location in the workcell changes periodically. If all the locations on the assembly are taught relative to the world coordinate frame, each time the assembly is located differently in the workcell, all the locations must be retaught. If, however, you create a frame based on identifiable features of the assembly, you will have to reteach only the points that define the frame.

Examples of Modifying Location Variables

Figure 7-6 shows how relative transformations work. The magnitude and direction elements (x, y, z), but not the orientation elements (y, p, r) of an Adept transformation can be represented as a 3D vector, as shown by dashed lines and arrows in Figure 7-6. The following code generates the locations shown in Figure 7-6.

```
; Define a simple transformation

    SET loc_a = TRANS(300,50,350,0,180,0)

; Move to the location

    MOVE loc_a
    BREAK

; Move to a location offset -50mm in X, 20mm in Y, and 30mm in Z
;    relative to "loc_a"

    MOVE loc_a:TRANS(-50, 20, 30)
    BREAK

; Define "loc_b" to be the current location relative to "loc_a"

    HERE loc_a:loc_b            ;loc_b = -50, 20, 30, 0, 0, 0
    BREAK

; Define "loc_c" as the vector sum of "loc_a" and "loc_b"

    SET loc_c = loc_a:loc_b     ;loc_c = 350, 70, 320, 0, 180, 0
```

Once this code has run, “loc_b” exists as a transformation that is completely independent of “loc_a”. The following instruction will move the robot move another –50mm in the x, 20mm in the y, and 30mm in the z direction (relative to “loc_c”):

```
MOVE loc_c:loc_b
```

Multiple relative transformations can be chained together. If we define “loc_d” to have the value 0, 50, 0, 0, 0, 0:

```
SET loc_d = TRANS(0,50)
```

and then issue the following MOVE instruction:

```
MOVE loc_a:loc_b:loc_d
```

the robot will move to a position x = –50mm, y =70mm, and z = 30mm relative to “loc_a”.

In Figure 7-6, the transformation “loc_b” defines the transformation needed to get from the local reference frame defined by “loc_a” to the local reference frame defined by “loc_c”. The transformation needed to go in the opposite direction (from “loc_c” to “loc_a”) can be calculated by:

```
INVERSE(loc_b)
```

Thus, the instruction:

```
MOVE loc_c:INVERSE(loc_b)
```

will effectively move the robot back to “loc_a”.

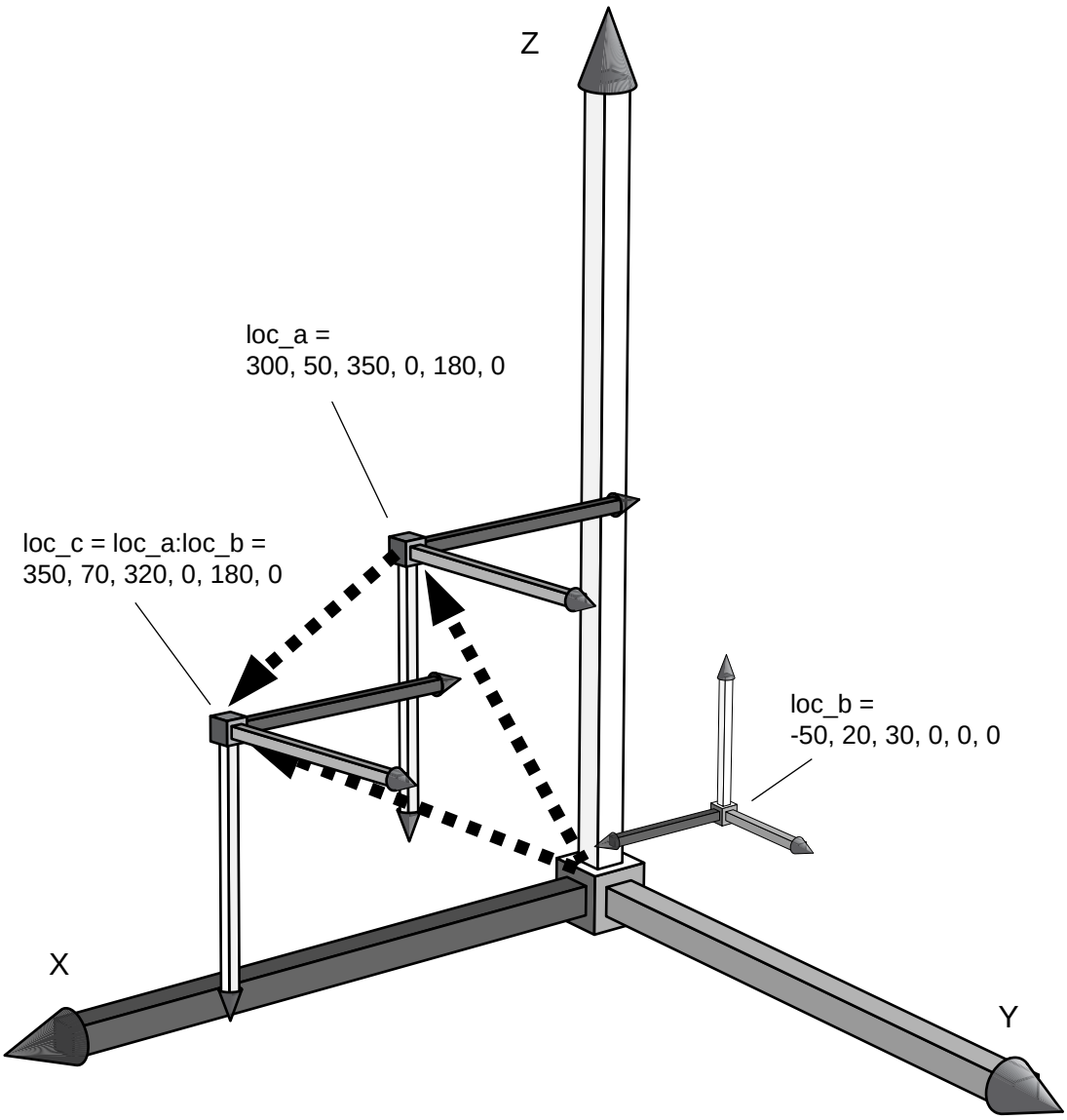

Figure 7-6. **Relative Transformation**

Figure 7-6 shows the first three locations from the code examples on page 122.

Defining a Reference Frame

In the example shown in Figure 7-7, a pallet is brought into the workcell on a conveyor. The program that follows will teach three locations that define the pallet reference frame (pallet.frame) and then remove the parts from the pallet. The program that follows will run regardless of where the pallet is placed in the workcell as long as it is within the robot working envelope.

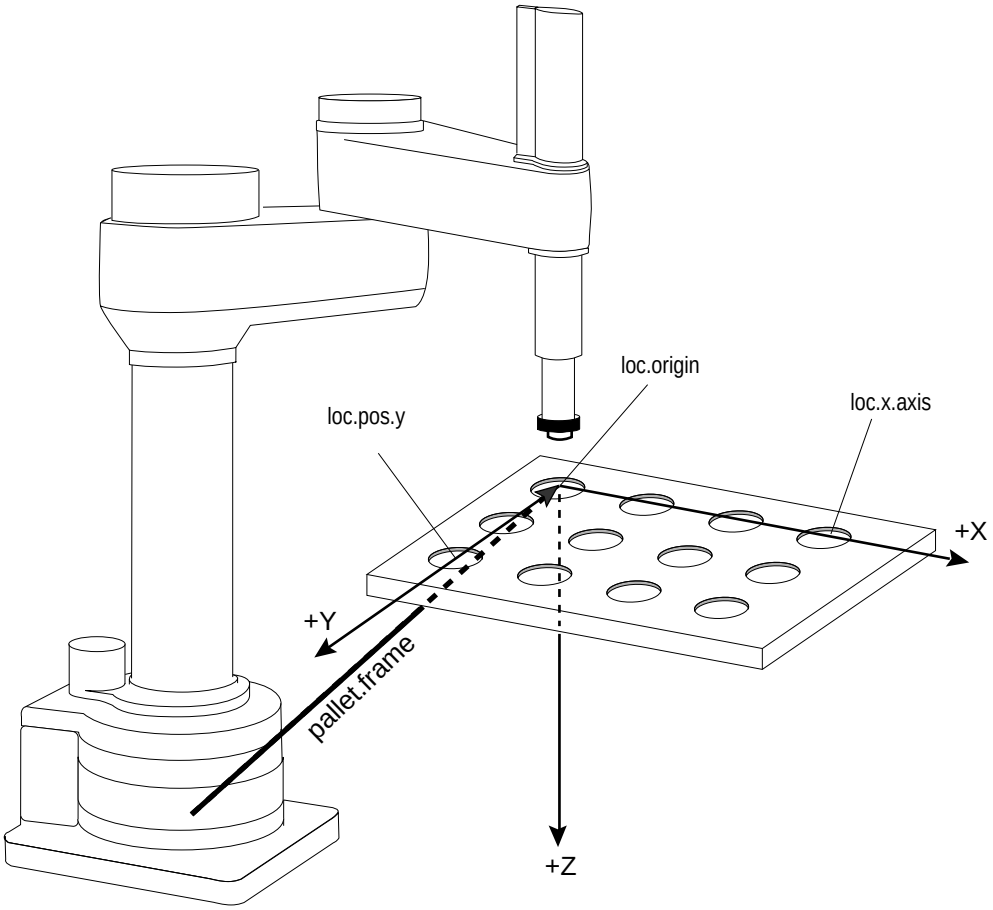

Figure 7-7. **Relative Locations**

```
; Get the locations to define the pallet

    DETACH ()                   ;Release robot for use by the MCP
    PROMPT "Place robot at pallet origin. ", $ans
    HERE loc.origin             ;Record the frame origin

    PROMPT "Place robot at point on the pallet x-axis. ", $ans
    HERE loc.x.axis             ;Record point on x-axis

    PROMPT "Place robot at point in positive y direction. ", $ans
    HERE loc.pos.y              ;Record positive y direction
```

```
    ATTACH ()                   ;Re-attach the robot

; Create the local reference frame "pallet.frame"

    SET pallet.frame = FRAME(loc.origin, loc.x.axis,loc.pos.y,
loc.origin)

    cell.space = 50             ;Spacing of cells on pallet

; Remove the palletized items

    FOR i = 0 TO 3
         FOR J = 0 TO 2
              APPRO pallet.frame:TRANS(i*cell.space, j*cell.space),
25
              MOVE pallet.frame:TRANS(i*cell.space, j*cell.space)
              BREAK             ;Settle robot
              CLOSEI            ;Grab the part
              DEPART 25         ;MOVE to the drop off location
         END
    END
```

In the above example, the code that teaches the pallet frame will need to be run only when the pallet location changes.

If you are building an assembly that does not have regularly spaced locations like the above example, the following code will teach individual locations relative to the frame:

```
; Get the locations to define the pallet frame

    DETACH ()                   ;Release robot for use by the MCP
    PROMPT "Place robot at assembly origin. ", $ans
    HERE loc.origin             ;Record the frame origin

    PROMPT "Place robot at point on the assm. x-axis. ", $ans
    HERE loc.x.axis             ;Record point on x-axis

    PROMPT "Place robot at point in positive y direction. ", $ans
    HERE loc.pos.y              ;Record positive y direction

; Create the local reference frame "assm.frame"

    SET assm.frame = FRAME(loc.origin, loc.x.axis, loc.pos.y,
loc.origin)

; Teach the locations on the assembly

    PROMPT "Place the robot in the first location. ", $ans
    HERE assm.frame:loc.1       ;Record the first location
```

```
    PROMPT "Place the robot in the second location. ", $ans
    HERE assm.frame:loc.2        ;Record the second location

    ; etc.

; Move to the locations on the assembly

    ATTACH ()                    ;Re-attach the robot

    APPRO assm.frame:loc.1, 25
    MOVE assm.frame:loc.1
    ;Activate gripper
    DEPART 25

    APPRO assm.frame:loc.1, 25
    MOVE assm.frame:loc.2
    ;Activate gripper
    DEPART 25

    ; etc.
```

In the above example, the frame will need to be taught each time the assembly moves—the locations on the assembly need to be taught only once.

The instruction “HERE assm.frame:loc.1” tells the system to record the location “loc.1” relative to “assm.frame” rather than relative to the world coordinate frame. If a sub-assembly is being built relative to “loc.1”, the instruction:

```
HERE assm.frame:loc.1:sub.loc.1
```

will create a compound transformation where “sub.loc.1” is relative to the transformation “assm.frame:loc.1”.

Miscellaneous Location Operations

The instruction:

```
DECOMPOSE array_name[] = #loc_name
```

will place the joint values of “#loc_name” in the array “array_name”. DECOMPOSE works with transformations and precision points.

The command:

```
WHERE
```

will display the current robot location.

The BASE operation can be used to realign the world reference frame relative to the robot.

7.4 Motion Control Instructions

V+ processes robot motion instructions differently from what you might expect. With V+, a motion instruction such as "MOVE part" is interpreted to mean "start moving the robot to location 'part'." As soon as the robot starts moving to the specified destination, the V+ program continues without waiting for the robot motion to complete. The instruction sequence:

```
MOVE part.1
SIGNAL 1
MOVE part.2
SIGNAL 2
```

will cause external output signal #1 to be turned on immediately after the robot begins moving to "part.1", rather than waiting for it to arrive at the location. When the second MOVE instruction is encountered, V+ waits until the motion to "part.1" is completed. External output signal #2 is turned on just after the motion to "part.2" begins. This is known as "forward processing". See "Breaking Continuous-Path Operation" on page 129 for details on how to defeat forward processing.

This parallel operation of program execution and robot motion makes possible the "procedural motions" described later in this chapter.

Basic Motion Operations

Joint-Interpolated Motion vs. Straight-Line Motion

The path a motion device takes when moving from one location to another can be either a joint-interpolated motion or a straight-line motion. Joint-interpolated motions move each joint at a constant velocity (except during the acceleration / deceleration phases—see "Robot Speed" on page 131). Typically, the robot tool tip moves in a series of arcs that represents the least processing intensive path the trajectory generator can formulate. Straight-line motions ensure that the robot tool tip traces a straight line, useful for cutting a straight line or laying a bead of sealant. The instruction:

```
MOVE pick
```

will cause the robot to move to the location "pick" using joint-interpolated motion. The instruction:

```
MOVES pick
```

will cause the robot to move the "pick" using a straight-line motion.

Safe Approaches and Departures

In many cases you will want to approach a location from distance offset along the tool Z axis or depart from a location along the tool Z axis before moving to the next location. For example, if you were inserting components into a crowded circuit board, you would want the robot arm to approach a location from directly above the board so nearby parts are not disturbed. Assuming you were using a four-axis Adept robot, the instructions:

```
APPRO place, 50
MOVE place
DEPART 50
```

will cause joint-interpolated motion to a point 50 mm above “place”, movement down to “place”, and movement straight up to 50 mm above “place”.

If the instructions APPROS, DEPARTS, and MOVES had been used, the motions would have been straight line instead of joint interpolated.

> **NOTE:** Approaches and departs are based on the tool coordinate system, not the world coordinate system. Thus, if the location specifies a pitch of 135°, the robot will approach at a 45° angle relative to the world coordinate system. See “Yaw” on page 117 for a description of the tool coordinate system.

Moving an Individual Joint

You can move an individual joint of a robot using the instruction DRIVE. The instructions:

```
DRIVE 2,50.0, 100
DRIVE 3,25, 100
```

will move joint 2 through 50° of motion and then move joint 3 a distance of 25 mm at SPEED 100x.

End Effector Operation Instructions

The instructions described in this section depend on the use of two digital signals. They are used to open, close, or relax a gripper. The utility program CONFIG_R specifies which signals control the end effector. See the *Instructions for Adept Utility Programs*.

The instruction OPEN will open the gripper during the ensuing motion instruction. The instruction OPENI will open the gripper before any additional motion instructions are executed. CLOSE and CLOSEI are the complementary instructions.

When an OPEN(I) or CLOSE(I) instruction is issued, one solenoid is activated and the other is released. To completely relax both solenoids, use the instruction RELAX or RELAXI.

Use the system parameter HAND.TIME to set the duration of the motion delay that occurs during an OPENI, CLOSEI, or RELAXI instruction.

Use the function HAND to return the current state of the gripper.

Continuous-Path Trajectories

When a single motion instruction is processed, such as the instruction:

```
MOVE pick
```

the robot begins moving toward the location by accelerating smoothly to the commanded speed. Sometime later, when the robot is close to the destination location “pick”, the robot will decelerate smoothly to a stop at location “pick”. This motion is referred to as a single “motion segment”, since it is produced by a single motion instruction.

When a sequence of motion instructions is executed, such as:

```
MOVE loc.1
MOVE loc.2
```

the robot begins moving toward "loc.1" by accelerating smoothly to the commanded speed[1] just as before. However, the robot will not decelerate to a stop when it gets close to "loc.1". Instead, it will smoothly change its direction and begin moving toward "loc.2". Finally, when the robot is close to "loc.2", it will decelerate smoothly to a stop at "loc.2". This motion consists of two "motion segments" since it is generated by two motion instructions.

Making smooth transitions between motion segments, without stopping the robot motion, is called continuous-path operation. That is the normal method V+ uses to perform robot motions. If desired, continuous-path operation can be disabled with the CP switch. When the CP switch is disabled, the robot will decelerate and stop at the end of each motion segment before beginning to move to the next location.

> **NOTE:** Disabling continuous-path operation does **not** affect forward processing (the parallel operation of robot motion and program execution).

Continuous-path transitions can occur between any combination of straight-line and joint-interpolated motions. For example, a continuous motion could consist of a straight-line motion (for example, DEPARTS) followed by a joint-interpolated motion (for example, APPRO) and a final straight-line motion (for example, MOVES). Any number of motion segments can be combined this way.

Breaking Continuous-Path Operation

Certain V+ program instructions cause program execution to be suspended until the current robot motion reaches its destination location and comes to a stop. This is called "breaking" continuous path. Such instructions are useful when the robot must be stopped while some operation is performed (for example, closing the hand). Consider the instruction sequence:

```
MOVE loc.1
BREAK
SIGNAL 1
```

The MOVE instruction starts the robot moving to "loc.1". Program execution then continues and the BREAK instruction is processed. BREAK causes the V+ program to wait until the motion to "loc.1" completes. The external signal will not be turned on until the robot stops. (Recall that without the BREAK instruction the signal would be turned on immediately after the motion to "loc.1" **starts**.)

The following instructions always cause V+ to suspend program execution until the robot stops (see *V+ Language Reference Guide* for detailed information on these instructions):

BASE	BREAK	CLOSEI	CPOFF	DETACH (0)
HALT	OPENI	PAUSE	RELAXI	TOOL

[1] See the SPEED monitor command and SPEED program instructions.

Also, the robot decelerates to a stop when the BRAKE (not to be confused with BREAK) instruction is executed (by any program task), and when the reaction associated with a REACTI instruction is triggered. These events could happen at any point within a motion segment. (Note that these events can be initiated from a different program task.)

The robot also decelerates and comes to a stop if no new motion instruction is encountered before the current motion completes. This situation can occur for a variety of reasons:

- A WAIT or WAIT.EVENT instruction is executed and the wait condition is not satisfied before the robot motion completes.
- A PROMPT instruction is executed and no response is entered before the robot motion completes.
- The V+ program instructions between motion instructions take longer to execute than the robot takes to perform its motion.

Procedural Motion

The ability to move in straight lines and joint-interpolated arcs is built into the basic operation of V+. The robot tool can also move along a path that is prerecorded, or described by a mathematical formula. Such motions are performed by programming the robot trajectory as the robot is moving. Such a program is said to perform a “procedural motion”.

A procedural motion is a program loop that computes many short motions and issues the appropriate motion requests. The parallel execution of robot motions and non-motion instructions allows each successive motion to be defined without stopping the robot. The continuous-path feature of V+ automatically smoothes the transitions between the computed motion segments.

Procedural Motion Examples

Two simple examples of procedural motions are described below. In the first example, the robot tool is moved along a trajectory described by locations stored in the array “path”. (The LAST function is used to determine the size of the array.)

```
SPEED 0.75 IPS ALWAYS

FOR index = 0 TO LAST(path[])
     MOVES path[index]
END
```

The robot tool will move at the constant speed of 0.75 inch per second through each location defined in the array “path[]”. (One way to create the “path” array is with the V+ TEACH command to move the robot along the desired path and repeatedly pressing the RECORD button on the manual control pendant.)

In the next example, the robot tool is to be moved along a circular arc. However, the path is not prerecorded—it is described mathematically, based on the radius and center of the arc to be followed.

The program segment below assumes that a real variable “radius” has already been assigned the radius of the desired arc, and “x.center” and “y.center” have been assigned the respective coordinates of the center of curvature. The variables “start” and “last” are

assumed to have been defined to describe the portion of the circle to be traced. Finally, the variable "angle.step" is assumed to have been defined to specify the (angular) increment to be traversed in each incremental motion. (Because the DURATION instruction is used, the program will move the robot tool "angle.step" degrees around the arc every 0.5 second.)

When this program segment is executed, the X and Y coordinates of points on the arc are repeatedly computed. They are then used to create a transformation that defines the destination for the next robot motion segment.

```
DURATION 0.5 ALWAYS
FOR angle = start TO last STEP angle.step
     x = radius*COS(angle)+x.center
     y = radius*SIN(angle)+y.center
     MOVE TRANS(x, y, 0, 0, 180, 0)
END
```

Timing Considerations

Because of the computation time required by V^+ to perform the transitions between motion segments, there is a limit on how closely spaced commanded locations can be. When locations are too close together, there is not enough time for V^+ to compute and perform the transition from one motion to the next, and there will be a break in the continuous-path motion. This means that the robot will stop momentarily at intermediate locations.

The minimum spacing that can be used between locations before this effect occurs is determined by the time required to complete the motion from one location to the next. Straight-line motions can be used if the motion segments take more than about 32 milliseconds each. Joint-interpolated motions can be used with motion segments as short as about 16 milliseconds each.

Robot Speed

A robot move has three phases: an acceleration phase where the robot accelerates to the maximum speed specified for the move, a velocity phase where the robot moves at a rate not exceeding the specified maximum speed, and a deceleration phase where the robot decelerates to a stop (or transitions to the next motion).

Robot speed can mean two things: how fast the robot moves between the acceleration and deceleration phases of a motion (referred to in this manual as robot speed), or how fast the robot gets from one place to another (referred to in this manual as robot performance).

The robot speed between the acceleration and deceleration phases is specified as either a percentage of "normal" speed or an absolute rate of travel of the robot tool tip. Speed set as a percentage of normal speed is the default. The speed of a robot move based on normal speed is determined by the following factors:

- The "program" speed (set with the SPEED program instruction). This speed is set to 100 when program execution begins.
- The "monitor" speed (set with the SPEED monitor command or a SPEED program instruction that specifies "MONITOR"). This speed is normally set to 50 at system startup (start-up SPEED can be set with the CONFIC_C utility). (The

effect of the two SPEED operations is slightly different. See the SPEED program instruction for further details.)

Robot speed is the product of these two speeds. With monitor speed and program speed set to 100, the robot will move at its “normal” speed. With monitor speed set to 50 and program speed set to 50, the robot will move at 25% of its “normal” speed.

To move the robot tool tip at an absolute rate of speed, a speed rate in inches per second or millimeters per second is specified in the SPEED program instruction. The instruction:

```
SPEED 25, MMPS ALWAYS
```

specifies an absolute tool tip speed of 25 millimeters per second for all robot motions until the next SPEED instruction. In order for the tool tip to actually move at the specified speed:

- The monitor speed must be 100.
- The locations must be far enough apart that the robot can accelerate to the desired speed and decelerate to a stop at the end of the motion.

Robot performance is a function of the SPEED settings and the following factors:

- The robot acceleration profile and ACCEL settings. The default acceleration profile is based on a “normal” maximum rate of acceleration and deceleration. The ACCEL command can scale down these maximum rates so the robot acceleration and/or deceleration takes more time.

  You can also define optional acceleration profiles that alter the maximum rate of change for acceleration and deceleration (using the “SPEC” utility).

- The location “tolerance” settings (COARSE/FINE, NULL/NONULL) for the move. The more accurately a robot must get to the actual location, the more time the move will take. (For AdeptMotion VME devices, the meaning of COARSE/FINE is set with the “SPEC” utility.)
- Any DURATION setting. DURATION forces a robot move to take a minimum time to complete regardless of the SPEED settings.
- The maximum allowable velocity. For Adept robots, this is factory set. For AdeptMotion VME devices, this is set with the “SPEC” utility.
- The inertial loading of the robot and the tuning of the robot.
- Straight-line vs. joint-interpolated motions—for complex geometries, straight-line and joint-interpolated paths produce different dynamic responses and, therefore, different motion times.

Robot performance for a given application can be greatly enhanced or severely degraded by these settings. For example:

- A heavily loaded robot may actually show better performance with slower SPEED and ACCEL settings, which will lessen overshoot at the end of a move and allow the robot to settle more quickly.
- Applications such as picking up bags of product with a vacuum gripper do not require high accuracy and can generally run faster with a COARSE tolerance.

Motion Modifiers

The following instructions modify the characteristics of individual motions. These instructions are summarized in Table 7-1

ACCEL	BRAKE	BREAK	COARSE*
FINE*	DURATION*	SPEED*	ABOVE/BELOW
CPON/CPOFF	FLIP/NOFLIP	LEFTY/RIGHTY	NULL/NONULL*
SINGLE/MULTIPLE*			

*Instructions that can take ALWAYS as an argument.

7.5 Tool Transformations

A tool transformation is a special transformation that is used to account for robot grippers (or parts held in grippers) that are offset from the center of the robot tool flange. If a location is taught using a part secured by an offset gripper, the actual location recorded is not the part location, but the center of the tool flange the offset gripper is attached to (see Figure 7-8). If the same location is taught with a tool transformation in place, the location recorded will be the center of the gripper, not the center of the tool flange. This allows you to change grippers and still have the robot reach the correct location. Figure 7-8 shows the location of the robot when a location is taught and the actual location that is recorded when no tool transformation is in effect. If the proper tool transformation is in effect when the location is taught, the location recorded will be the part location and not the center of the tool flange.

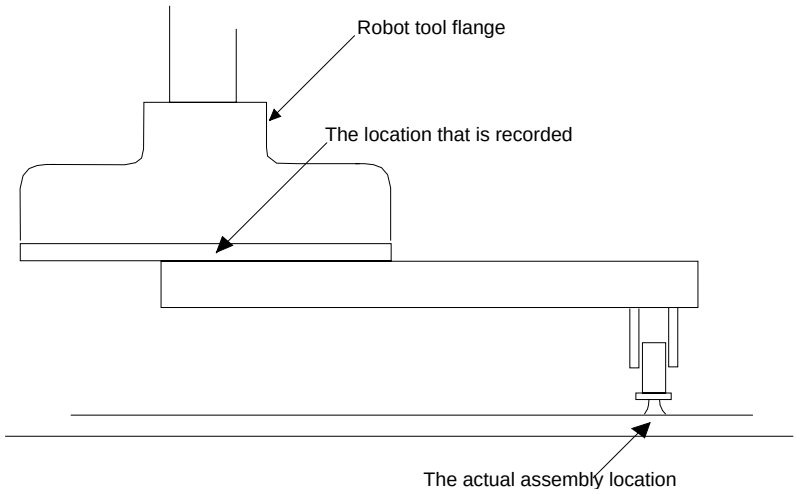

Figure 7-8. **Recording Locations**

Defining a Tool Transformation

If the dimensions of a robot tool are known, the POINT command can be used to define a tool transformation to describe the tool. The "null tool" has its center at the surface of the tool mounting flange and its coordinate axes parallel to that of the last joint of the robot. The null tool transformation is equal to [0,0,0,0,0,0].

For example, if your tool has "fingers" that extend 50 mm below the tool flange and 100 mm in the tool x direction, and you want to change the tool setting to compensate for the offset, enter the following lines at the system prompt (bold characters indicate those actually entered):

```
.POINT hand.tool↵                    (create a new transformation)
        X    Y    Z    y    p    r
        0.00 0.00 0.00 0.000 0.000 0.000
Change? ,100,-50↵                    (alter it by the grip offset)
        0.00 100.00 -50.00 0.000 0.000 0.000
Change? ↵
.TOOL hand.tool↵
.LISTL hand.tool↵
    X.jt1    y/jt2    z/jt3    y/jt4    p/jt5    r/jt6
    0.00     100.00  -50.00    0.000    0.000    0.000
```

Figure 7-9 shows the TOOL that would result from the above operation.

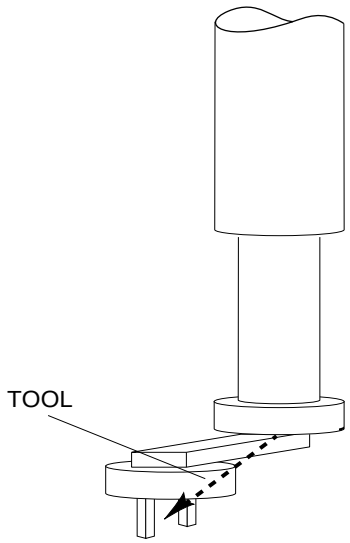

Figure 7-9. **Tool Transformation**

Tool transformations are most important when:

- Grippers are changed frequently
- The robot is vision guided
- Robot locations are loaded directly from CAD data

7.6 Summary of Motion Keywords

The following table summarizes the keywords associated with motion in V+.

These instructions are covered in detail in the *V+ Language Reference Guide*. Please see the reference guide for the keyword parameters and their use.

Table 7-1. **Motion Control Operations**

Keyword	Type	Function
ABOVE	PI	Request a change in the robot configuration during the next motion so that the elbow is above the line from the shoulder to the wrist.
ACCEL	PI	Set acceleration and deceleration for robot motions.
ACCEL	RF	Return the current robot acceleration or deceleration setting.
ALIGN	PI	Align the robot tool Z axis with the nearest world axis.
ALTER	PI	Specify the magnitude of the real-time path modification that is to be applied to the robot path during the next trajectory computation.
ALTOFF	PI	Terminate real-time path-modification mode ("alter" mode).
ALTON	PI	Enable real-time path-modification mode ("alter" mode), and specify the way in which ALTER coordinate information will be interpreted.
AMOVE	PI	Position an "extra" robot axis during the next joint-interpolated or straight-line motion.
APPRO	PI	Start joint-interpolated robot motion toward a location defined relative to specified location.
APPROS	PI	Start straight-line robot motion toward a location defined relative to specified location.
BASE	PI	Translate and rotate the world reference frame relative to the robot.
BASE	TF	Return the transformation value that represents the translation and rotation set by the last BASE command or instruction.
BELOW	PI	Request a change in the robot configuration during the next motion so that the elbow is below the line from the shoulder to the wrist.

PI: Program Instruction, RF: Real-Valued Function, TF: Transformation Function, S: Switch, P: Parameter, PF: Precision-Point Function, SF: String Function, CF: Conversion Factor

Table 7-1. **Motion Control Operations** (Continued)

Keyword	Type	Function
BRAKE	PI	Abort the current robot motion.
BREAK	PI	Suspend program execution until the current motion completes.
CALIBRATE	PI	Initialize the robot positioning system.
CLOSE	PI	Close the robot gripper immediately.
CLOSEI	PI	Close the robot gripper.
COARSE	PI	Enable a low-precision feature of the robot hardware servo (see FINE).
CONFIG	RF	Return a value that provides information about the robot's geometric configuration, or the status of the motion servo-control features.
CP	S	Control the continuous-path feature.
CPOFF	PI	Instruct the V+ system to stop the robot at the completion of the next motion instruction (for all subsequent motion instructions) and null position errors.
CPON	PI	Instruct the V+ system to execute the next motion instruction (or all subsequent motion instructions) as part of a continuous path.
DECOMPOSE	PI	Extract the (real) values of individual components of a location value.
DELAY	PI	Cause robot motion to stop for the specified period of time.
DEPART	PI	Start a joint-interpolated robot motion away from the current location.
DEPARTS	PI	Start a straight-line robot motion away from the current location.
DEST	TF	Return a transformation value representing the planned destination location for the current robot motion.
DISTANCE	RF	Determine the distance between the points defined by two location values.
DRIVE	PI	Move an individual joint of the robot.
DRY.RUN	S	Control whether or not V+ communicates with the robot.
DURATION	PI	Set the minimum execution time for subsequent robot motions.
DURATION	RF	Return the current setting of one of the motion DURATION specifications.
DX	RF	Return a displacement component of a given transformation value.

PI: Program Instruction, RF: Real-Valued Function, TF: Transformation Function, S: Switch, P: Parameter, PF: Precision-Point Function, SF: String Function, CF: Conversion Factor

Table 7-1. **Motion Control Operations** (Continued)

Keyword	Type	Function
DY	RF	Return a displacement component of a given transformation value.
DZ	RF	Return a displacement component of a given transformation value.
FINE	PI	Enable a high-precision feature of the robot hardware servo (see COARSE).
FLIP	PI	Request a change in the robot configuration during the next motion so that the pitch angle of the robot wrist has a negative value (see NOFLIP).
FORCE	S	Control whether or not the (optional) stop-on-force feature of the V+ system is active.
FRAME	TF	Return a transformation value defined by four positions.
HAND	RF	Return the current hand opening.
HAND.TIME	P	Establish the duration of the motion delay that occurs during OPENI, CLOSEI, and RELAXI instructions.
HERE	PI	Set the value of a transformation or precision-point variable equal to the current robot location.
HERE	TF	Return a transformation value that represents the current location of the robot tool point.
HOUR.METER	RF	Return the current value of the robot hour meter.
IDENTICAL	RF	Determine if two location values are exactly the same.
INRANGE	RF	Return a value that indicates if a location can be reached by the robot, and if not, why not.
INVERSE	TF	Return the transformation value that is the mathematical inverse of the given transformation value.
IPS	CF	Specify the units for a SPEED instruction as inches per second.
LATCH	TF	Return a transformation value representing the location of the robot at the occurrence of the last external trigger.
LATCHED	RF	Return the status of the external trigger, and of the information it causes to be “latched”.
LEFTY	PI	Request a change in the robot configuration during the next motion so that the first two links of a SCARA robot resemble a human’s left arm (see RIGHTY).
MMPS	CF	Specify the units for a SPEED instruction as millimeters per second.

PI: Program Instruction, RF: Real-Valued Function, TF: Transformation Function, S: Switch, P: Parameter, PF: Precision-Point Function, SF: String Function, CF: Conversion Factor

Table 7-1. **Motion Control Operations** (Continued)

Keyword	Type	Function
MOVE	PI	Initiate a joint-interpolated robot motion to the position and orientation described by the given location.
MOVES	PI	Initiate a straight-line robot motion to the position and orientation described by the given location.
MOVEF	PI	Initiate a three-segment pick-and-place joint-interpolated robot motion to the specified destination, moving the robot at the fastest allowable speed.
MOVESF	PI	Initiate a three-segment pick-and-place straight-line robot motion to the specified destination, moving the robot at the fastest allowable speed.
MOVET	PI	Initiate a joint-interpolated robot motion to the position and orientation described by the given location and simultaneously operate the hand.
MOVEST	PI	Initiate a straight-line robot motion to the position and orientation described by the given location and simultaneously operate the hand.
MULTIPLE	PI	Allow full rotations of the robot wrist joints (see SINGLE).
NOFLIP	PI	Request a change in the robot configuration during the next motion so that the pitch angle of the robot wrist has a positive value (see FLIP).
NONULL	PI	Instruct the V+ system not to wait for position errors to be nulled at the end of continuous-path motions (see NULL).
NORMAL	TF	Correct a transformation for any mathematical round-off errors.
NOT.CALIBRATED	P	Indicate (or assert) the calibration status of the robots connected to the system.
NULL	TF	Return a null transformation value—one with all zero components.
NULL	PI	Enable nulling of joint position errors.
OPEN	PI	Open the robot gripper.
OPENI	PI	Open the robot gripper immediately.
PAYLOAD	PI	Set an indication of the current robot payload.
#PDEST	PF	Return a precision-point value representing the planned destination location for the current robot motion.
#PLATCH	PF	Return a precision-point value representing the location of the robot at the occurrence of the last external trigger.

PI: Program Instruction, RF: Real-Valued Function, TF: Transformation Function, S: Switch, P: Parameter, PF: Precision-Point Function, SF: String Function, CF: Conversion Factor

Table 7-1. **Motion Control Operations** (Continued)

Keyword	Type	Function
POWER	S	Control or monitor the status of Robot Power.
#PPOINT	PF	Return a precision-point value composed from the given components.
REACTI	PI	Initiate continuous monitoring of a specified digital signal. Automatically stop the current robot motion if the signal properly transitions and optionally trigger a subroutine call.
READY	PI	Move the robot to the READY location above the workspace, which forces the robot into a standard configuration.
RELAX	PI	Limp the pneumatic hand.
RELAXI	PI	Limp the pneumatic hand immediately.
RIGHTY	PI	Request a change in the robot configuration during the next motion so that the first two links of the robot resemble a human's right arm (see LEFTY).
ROBOT	S	Enable or disable one robot or all robots.
RX	TF	Return a transformation describing a rotation about the x axis.
RY	TF	Return a transformation describing a rotation about the y axis.
RZ	TF	Return a transformation describing a rotation about the z axis.
SCALE	TF	Return a transformation value equal to the transformation parameter with the position scaled by the scale factor.
SELECT	PI	Select the unit of the named device for access by the current task.
SET	PI	Set the value of the location variable on the left equal to the location value on the right of the equal sign.
SET.SPEED	S	Control whether or not the monitor speed can be changed from the manual control pendant. The monitor speed cannot be changed when the switch is disabled.
SHIFT	TF	Return a transformation value resulting from shifting the position of the transformation parameter by the given shift amounts.
SINGLE	PI	Limit rotations of the robot wrist joint to the range –180 degrees to +180 degrees (see MULTIPLE).
SOLVE.ANGLES	PI	Compute the robot joint positions (for the current robot) that are equivalent to a specified transformation.
SOLVE.FLAGS	RF	Return bit flags representing the robot configuration specified by an array of joint positions.

PI: Program Instruction, RF: Real-Valued Function, TF: Transformation Function, S: Switch, P: Parameter, PF: Precision-Point Function, SF: String Function, CF: Conversion Factor

Table 7-1. **Motion Control Operations** (Continued)

Keyword	Type	Function
SOLVE.TRANS	PI	Compute the transformation equivalent to a given set of joint positions for the current robot.
SPEED	PI	Set the nominal speed for subsequent robot motions.
SPEED	RF	Return one of the system motion speed factors.
STATE	RF	Return a value that provides information about the robot system state.
TOOL	PI	Set the internal transformation used to represent the location and orientation of the tool tip relative to the tool mounting flange of the robot.
TOOL	TF	Return the value of the transformation specified in the last TOOL command or instruction.
TRANS	TF	Return a transformation value computed from the given X, Y, Z position displacements and y, p, r orientation rotations.
TRANSB	TF	Return a transformation value represented by a 48-byte string.

PI: Program Instruction, RF: Real-Valued Function, TF: Transformation Function, S: Switch, P: Parameter, PF: Precision-Point Function, SF: String Function, CF: Conversion Factor

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8.1 Terminal I/O

The program instruction used to output text to the monitor screen is TYPE. The program line:

```
TYPE "This is a terminal output instruction."
```

will output the text between the quotation marks to the current cursor location. If a variable “x” has a value of 27, the instruction:

```
TYPE "The value of x is ", x, "."
```

will output “The value of x is 27.” to the monitor.

The TYPE instruction has qualifiers for entering blank spaces and moving the cursor. The instruction:

```
TYPE /C34, /U17, "This is the screen center."
```

will enter 34 carriage returns (clear the screen), move up 17 lines from the bottom of the screen, and output the text message. Additional qualifiers are available to format the output of variables and control terminal behavior.

The program instruction used to retrieve data input from the keyboard is PROMPT. The program line:

```
PROMPT "Enter a value for x: ", x
```

will halt program execution and wait for the operator to enter a value from the keyboard (in this case a real or integer value). If a value of the proper data type is entered, the value is assigned to the named variable (if the variable does not exist, it will be created and assigned the value entered) and program execution will proceed. If an improper data type is entered, the system will generated an error message and halt execution. String data is expected if a string variable (“$x”, for example) is specified.

All terminal input should be checked for proper data type. The following code segment will insure that a positive integer is input. (Using the VAL() function also guarantees that inadvertently entered non-numeric characters will not cause a system error.)

```
DO
     PROMPT "Enter a value greater than 0: ", $x
     x = VAL($x)
UNTIL x > 0
```

Terminal Types

In order for V+ to echo input characters properly and to generate certain displays on character based terminals, the type of terminal being used must be specified to the system. The default terminal type (which is recorded on the V+ system disk) is assumed each time the V+ system is booted from disk.[1] After the system is booted, the TERMINAL system parameter can be set to specify a different terminal type.

[1] The default terminal type and communication characteristics of the serial line are set with the configuration program in the file CONFIG_C.V2 on the Adept Utility Disk.

Input Processing

Terminal input is buffered by the system but is not echoed until it is actually read by the V+ monitor or by a program. A maximum of 80 characters can be received before V+ begins to reject input. When input is being rejected, V+ beeps the terminal for each character rejected.

On input, V+ may intercept special characters Ctrl+O, Ctrl+Q, and Ctrl+S, and use them to control terminal output.[1] They cannot be input even by the GETC function. Their functions are shown in the table below.

Char.	Decimal	Function
Ctrl+O	15	Suppress or stop suppressing output
Ctrl+Q	17	Resume output suspended by Ctrl+S
Ctrl+S	19	Immediately suspend terminal output

When Ctrl+O is used to suppress output, all output instructions behave normally, except that no output is sent to the terminal. Output suppression is canceled by typing a second Ctrl+O, by V+ writing a system error message, or by a terminal read request.

Other special characters are recognized by the terminal input handler when processing a PROMPT or READ instruction, or when reading a monitor command. However, these characters can be read by the GETC function, in which case their normal action is suppressed.

Char.	Decimal	Name	Action
Ctrl+C	03		Abort the current monitor command
Ctrl+H	08	Backspace	Delete the previous input character
Ctrl+I	09	Tab	Move to the next tab stop
Ctrl+M	13	Return	Complete this input line
Ctrl+R	18		Retype the current input line
Ctrl+U	21		Delete the entire current line
Ctrl+W	23		Start/stop slow output mode
Ctrl+Z	26		Complete this input with an “end of file” error
DEL	127	Delete	Delete the previous input character

During a PROMPT or READ instruction, all control characters are ignored except those listed above. Tab characters are automatically converted to the appropriate number of

[1] Terminal behavior is configurable using the /FLUSH and /FLOW arguments to the FSET instruction. See the *V+ Language Reference Guide.*

space characters when they are received. (Tab stops are assumed to be set every eight spaces [at columns 9, 17, 25,...] and cannot be changed.)

The most significant bit of each byte is forced to zero.

Unlike PROMPT, both READ and GETC require that the terminal be ATTACHed.

Normally, READ and GETC echo input characters as they are processed. An optional mode argument for each of these operations allows echo to be suppressed.

Output Processing

Output to the system terminal can be performed using PROMPT, TYPE, or WRITE instructions. All eight-bit, binary, byte data is output to the terminal without any modification.

TYPE and WRITE automatically append a Return character (13 decimal) and Line Feed character (10 decimal) to each data record, unless the "/S" format control is specified. PROMPT does not append any characters.

Unlike all the other I/O devices, the terminal does not have to be attached prior to output requests. If a different task is attached to the terminal, however, any output requests are queued until the other task detaches. V+ system error messages are always displayed immediately, regardless of the status of terminal attachment.

8.2 Digital I/O

Adept controllers can communicate in a digital fashion with external devices using the Digital I/O capability. Digital input reads the status of a signal controlled by user-installed equipment. A typical digital input operation would be to wait for a microswitch on a workcell conveyor to close indicating that an assembly is in the proper place. The WAIT instruction and SIG function are used to halt program execution until a digital input channel signal achieves a specified state. The program line:

```
WAIT SIG(1001)
```

will halt program execution until a switching device attached to digital input channel 1001 is closed. If signal 1002 is a sensor indicating a part feeder is empty, the code:

```
IF SIG(1002) THEN
     CALL service.feeder()
END
```

will check the sensor state and call a routine to service the feeder if the sensor is on.

The SIGNAL instruction is used for digital output. In the above example, the conveyor belt may need to be stopped after digital input signal 1001 signals that a part is in place. The instruction:

```
SIGNAL(-33)
```

will turn off digital output signal 33, causing the conveyor belt connected to signal 33 to stop. When processing on the part is finished and the part needs to be moved out of the work area, the instruction:

```
SIGNAL(33)
```

will turn the conveyor belt back on. The digital I/O channels must be installed before they can be accessed by the SIG function or SIGNAL instruction.[1] The SIG.INS function returns an indication of whether a given signal number is available. The code line:

```
IF SIG.INS(33) THEN
```

can be used to insure that a digital signal was available before you attempted to access it. The monitor command IO will display the status of all digital I/O channels. See the *Adept MV Controller User's Guide* for details on installing digital I/O hardware.

Digital output channels are numbered from 1 to 232. Input channels are in the range 1001 to 1236.

High-Speed Interrupts

Normally, the digital I/O system is checked once every V+ major cycle (every 16ms). In some cases, the delay or uncertainty resulting may be unacceptable. Digital signals 1001 - 1003 can be configured as high-speed interrupts. When a signal configured as a high-speed interrupt transitions, its state is read at system interrupt level, resulting in a maximum delay of 1ms. The controller configuration utility "CONFIG_C" is used to configure high-speed interrupts.

Soft Signals

Soft signals are used primarily as global flags. The soft signals are in the range 2001-2512 and can be used with SIG and SIGNAL. A typical use of soft signals is for inter-task communication. See "REACT, REACTI" on page 80 and the REACT_ instructions in the *V+ Language Reference Guide*.

Soft signals may be used to communicate between different V+ systems running on multiple system processors.[2]

8.3 Pendant I/O

Most of the standard V+ I/O operations can be used to read data from the manual control pendant keypad and to write data to the pendant display. See Chapter 10 for information on accessing the manual control pendant.

---

[1] See the "CONFIG_C" utility in the *Instructions for Adept Utility Programs* for details on configuring digital I/O. See the controller user's guide for details on installation.

[2] If your system is equipped with multiple system processors and the optional V+ Extensions software, you can run different copies of V+ on each processor. Use the CONFIG_C utility to set up multiple V+ systems.

8.4 Analog I/O

Up to eight analog I/O modules for a total of 32 output and 256 input channels[1] can be installed in an Adept MV controller. Figure 8-1 shows the I/O channel numbers for each installed module. Analog I/O modules can be configured for different input/output ranges. The actual input and output voltages are determined by setting on the AIO module. Regardless of the input/output range selected, the AIO.IN function returns a value in the –1.0 to 1.0 range and AIO.OUT instruction expects a value in the range –1.0 to 1.0. Additionally, modules can be configured for differential input (which reduces the maximum number of input channels to 128.) See the *Adept MV Controller User's Guide* for details on installing and configuring analog I/O boards.

The instruction:

```
analog.value = AIO.IN(1004)
```

will read the current state of analog input channel 4.

The instruction:

```
AIO.OUT 2 = 0.9
```

will write the value 0.9 to analog output channel 2.

The instruction:

```
IF AIO.INS (4) THEN
     AIO.OUT 4 = 0.56
END
```

will write to output channel 4 only if output channel 4 is installed.

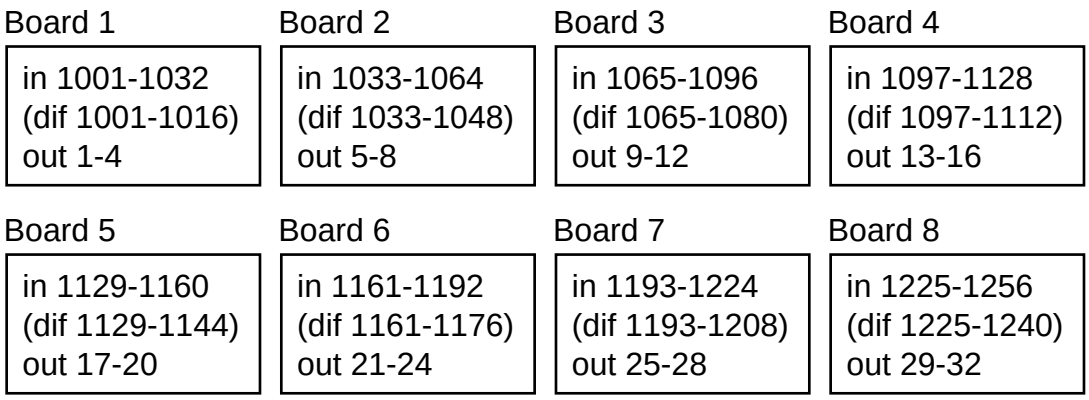

Figure 8-1. **Analog I/O Board Channels**

[1] Analog I/O boards can be configured for differential input rather than single-ended input. Differential input reduces the number of channels on a single board from 32 to 16.

8.5 Serial and Disk I/O Basics

The following sections describe the basic procedures that are common to both serial and disk I/O operations. Section 8.6 covers disk I/O in detail. Section 8.8 covers serial I/O in detail.

Logical Units

All V+ serial and disk I/O operations reference an integer value called a "Logical Unit Number" or LUN. The LUN provides a shorthand method of identifying which device or file is being referenced by an I/O operation. See the ATTACH command in the *V+ Language Reference Guide* for the default device LUN numbers.

Disk devices are different from all the other devices in that they allow files to be opened. Each program task can have one file open on each disk LUN. That is, each program task can have multiple files open simultaneously (on the same or different disk units).

> **NOTE:** No more than 60 disk files can be open by the entire system at any time. That includes files opened by programs and by the system monitor (for example, for the FCOPY command). The error "*Device not ready*" results if an attempt is made to open a 61st file.

See Chapter 9 for details on accessing the graphics window LUNs.

Error Status

Unlike most other V+ instructions, I/O operations are expected to fail under certain circumstances. For example, when reading a file, an error status is returned to the program to indicate when the end of the file is reached. The program is expected to handle this error and continue execution. Similarly, a serial line may return an indication of a parity error, which should cause the program to retry a data transmission sequence.

For these reasons, V+ I/O instructions normally do not stop program execution when an error occurs. Instead, the success or failure of the operation is saved internally for access by the IOSTAT real-valued function. For example, a reference to IOSTAT(5) will return a value indicating the status of the last I/O operation performed on LUN 5. The values returned by IOSTAT fall into one of following three categories:

Value	Explanation
1	The I/O operation completed successfully.
0	The I/O operation has not yet completed. This value appears only if a pre-read or no-wait I/O is being performed.
<0	The I/O operation completed with an error. The error code indicates what type of error occurred.

The error message associated with a negative value from IOSTAT can be found in the *V+ Language Reference Guide*. The $ERROR string function can be used in a program (or with the LISTS monitor command) to generate the text associated with most I/O errors.

It is good practice to use IOSTAT to check each I/O operation performed, even if you think it cannot fail (hardware problems can cause unexpected errors).

Note that it is not necessary to use IOSTAT after use of a GETC function, since errors are returned directly by the GETC function.

Attaching/Detaching Logical Units

In general, an I/O device must be attached using the ATTACH instruction before it can be accessed by a program. Once a specific device (such as the manual control pendant) is attached by one program task, it cannot be used by another program task. Most I/O requests fail if the device associated with the referenced LUN is not attached.

Each program task has its own sets of disk and graphics logical units. Thus, more than one program task can attach the same logical unit number in those groups at the same time without interference.

A physical device type can be specified when the logical unit is attached. If a device type is specified, it supersedes the default, but only for the logical unit attached. The specified device type remains selected until the logical unit is detached.

An attach request can optionally specify “immediate” mode. Normally, an attach request is queued and the calling program is suspended if another control program task is attached to the device. When the device is detached, the next attachment in the queue will be processed. In immediate mode, the ATTACH instruction completes immediately, with an error if the requested device is already attached by another control program task.

With V+ systems, attach requests can also specify “no-wait” mode. This mode allows an attach request to be queued without forcing the program to wait for it to complete. The IOSTAT function must then be used to determine when the attach has completed.

If a task is already attached to a logical unit, it will get an error immediately if it attempts to attach again without detaching, regardless of the type of wait mode specified.

When a program is finished with a device, it should detach the device with the DETACH program instruction. This allows other programs to process any pending I/O operations.

When a control program completes execution normally, all I/O devices attached by it are automatically detached. If a program stops abnormally, however, most device attachments are preserved. If the control program task is resumed and attempts to reattach these logical units, it may fail because of the attachments still in effect. The KILL monitor command forces a program to detach all the devices it has attached.

If attached by a program, the terminal and manual control pendant are detached whenever the program halts or pauses for any reason, including error conditions and single-step mode. If the program is resumed, the terminal and the manual control pendant are automatically reattached if they were attached before the termination.

> **NOTE:** It is possible that another program task could have attached the terminal or manual control pendant in the meantime. That would result in an error message when the stopped task is restarted.

Reading

The READ instruction processes input from all devices. The basic READ instruction issues a request to the device attached on the indicated LUN, and waits until a complete data record is received before program execution continues. (The length of the last record read can be obtained with the IOSTAT function with its second argument set to 2.)

The GETC real-valued function returns the next data byte from an I/O device without waiting for a complete data record. It is commonly used to read data from the serial lines or the system terminal. It also can be used to read disk files in a byte-by-byte manner.

Special mode bits to allow reading with no echo are supported for terminal read operations. Terminal input also can be performed using the PROMPT instruction.

The GETEVENT instruction can be used to read input from the system terminal. This may be useful in writing programs that operate on both A-series and S-series controllers.

To read data from a disk device, a file must be open on the corresponding logical unit. The FOPEN_ instructions open disk files.

Writing

The WRITE instruction processes output to serial and disk devices and to the terminal. The basic WRITE instruction issues a request to the device attached on the indicated LUN, and waits until the complete data record is output before program execution continues.

WRITE instructions accept format control specifiers that determine how output data is formatted, and whether or not an “end of record” mark should be written at the end of the record.

Terminal output also can be performed using the PROMPT or TYPE instructions.

A file must be open using the FOPENW or FOPENA instructions before data can be written to a disk device. FOPENW opens a new file. FOPENA opens an existing file and appends data to that file.

Input Wait Modes

Normally, V+ waits until the data from an input instruction is available before continuing with program execution. However, the READ instruction and GETC function accept an optional argument that specifies “no-wait” mode. In no-wait mode, these instructions return immediately with the error status –526 (No data received) if there is no data available. A program can loop and use these operations repeatedly until a successful read is completed, or until some other error is received.

The disk devices do not recognize no-wait mode on input, and treat such requests as normal input-with-wait requests.

Output Wait Modes

Normally, V+ waits for each I/O operation to be complete before continuing to the next program instruction. For example, the instruction:

```
TYPE /X50
```

causes V+ to wait for the entire record of 50 spaces to be transmitted (about 50 milliseconds with the terminal set to 9600 baud) before continuing to the next program instruction.

Similarly, WRITE instructions to serial lines or disk files will wait for any required physical output to complete before continuing.

This waiting is not performed if the "/N" ("no wait") format control is specified in an output instruction. Instead, V+ immediately executes the next instruction. The IOSTAT function will check whether or not the output has completed. It returns a value of zero if the previous I/O is not complete.

If a second output instruction for a particular LUN is encountered before the first no-wait operation has completed, the second instruction will automatically wait until the first is done. This scheme means the no-wait output is effectively double buffered. If an error occurs in the first operation, the second operation is canceled and the IOSTAT value is correct for the first operation.

With V+, the IOSTAT function can be used with a second argument of "3" to explicitly check for the completion of a no-wait write.

8.6 Disk I/O

Attaching Disk Devices

A disk LUN refers to a local disk device, such as a 3-1/2 inch diskette drive or the optional hard disk. Also, a remote disk may be accessed via the Kermit protocol or a network.

The type of device to be accessed is determined by the DEFAULT command or the ATTACH instruction. If the default device type set by the DEFAULT command is not appropriate at a particular time, the ATTACH instruction can be used to override the default. The syntax of the ATTACH instruction is:

```
ATTACH (lun, mode) $device
```

See the description of ATTACH in the *V+ Language Reference Guide* for the mode options and the possible "$device" names. The instruction:

```
ATTACH (dlun, 4) "DISK"
```

will attach to an available disk logical unit and return the number of the logical unit in the variable "dlun", which can then be used in other disk I/O instructions.

If the device name is omitted from the instruction, the default device for the specified LUN is used. Adept recommends that you always specify a device name with the ATTACH instruction. (The device "SYSTEM" refers to the device specified with the DEFAULT monitor command.)

Once the attachment is made, the device cannot be changed until the logical unit is detached. However, any of the units available on the device can be specified when opening a file. For example, the V+ "DISK" units are "A" and "C". After attaching a "DISK" device LUN, a program can open and close files on either of these disk units before detaching the LUN.

Disk Directories

The FOPEN_ instructions, which open disk files for reading and writing, use directory paths in the same fashion as the monitor commands LOAD, STORE, etc. Files on a disk are grouped in "directories". If a disk is thought of as a file cabinet, then a directory can be thought of as a drawer in that cabinet. Directories allow files (the file folders in our file cabinet analogy) that have some relationship to each other to be grouped together and separated from other files. See the chapter "Using Files" in the *V+ Operating System User's Guide* for more details on the directory structure.

Disk File Operations

All I/O requests to a disk device are made to a file on that device. A disk file is a logical collection of data records[1] on a disk. Each disk file has a name, and all the names on a disk are stored in a directory on the disk. The FDIRECTORY monitor command displays the names of the files on a disk.

[1] A variable-length "record" is a text string terminated by a CR/LF (ASCII 13/ASCII 10).

A disk file can be accessed either "sequentially," where data records are accessed from the beginning of the file to its end, or "randomly," where data records are accessed in any order. Sequential access is simplest and is assumed in this section. Random access is described later in this chapter.

Opening a Disk File

Before a disk file can be opened, the disk the file is on must be ATTACHed.

The FOPEN_ instructions open disk files (and file directories). These instructions associate a LUN with a disk file. Once a file is open, the READ, GETC, and WRITE instructions access the file. These instructions use the assigned LUN to access the file so multiple files may be open on the same disk and the I/O operations for the different disk files will not affect each other.[1]

The simplified syntax for FOPEN_ is:

```
FOPEN_ (lun) file_spec
```

where:

`lun` logical unit number used in the ATTACH instruction

`file_spec` file specification in the form, `unit:path\filename.ext`

- unit — is an optional disk unit name. The standard local disk units are "A" and "C". If no unit is specified, the colon also must be omitted. Then the default unit (as determined by the DEFAULT command) is assumed.
- path\ — is an optional directory path string. The directory path is defined by one or more directory names, each followed by a "\" character. The actual directory path is determined by combining any specified path with the path set by the DEFAULT command. If "`path`" is preceded with a "\", the path is absolute. Otherwise, the path is relative and is added to the current DEFAULT path specification. (If "`unit`" is specified and is different from the default unit, the path is always absolute.)
- filename — is a name with 1 to 8 characters, which is used as the name of the file on the disk.
- ext — is the file name extension—a string with 0 to 3 characters, which is used to identify the file type.

The four open commands are:

1. Open for read only (FOPENR). If the disk file does not exist, an error is returned. No write operations are allowed, so data in the file cannot be modified.

[1] When accessing files on a remote system (for example, when using Kermit), the unit can be any name string, and the file name and extension can be any arbitrary string of characters.

2. Open for write (FOPENW). If the disk file already exists, an error is returned. Otherwise, a new file is created. Both read and write operations are allowed.

3. Open for append (FOPENA). If the disk file does not exist, a new file is created. Otherwise, an existing file is opened. No error is returned in either case. A sequential write or a random write with a zero record number appends data to the end of the file.

4. Open for directory read (FOPEND). The last directory in the specified directory path is opened. Only read operations are allowed. Each record read returns an ASCII string containing directory information. Directories should be opened using variable-length sequential-access mode.

While a file is open for write or append access, another control program task cannot access that file. However, multiple control program tasks can access a file simultaneously in read-only mode.

Writing to a Disk

The instruction:

```
WRITE (dlun) $in.string
```

will write the string stored in "$in.string" to the disk file open on "dlun". The instruction:

```
error = IOSTAT(dlun)
```

will return any errors generated during the write operation.

Reading From a Disk

The instruction:

```
READ (dlun) $in.string
```

will read (from the open file on "dlun") up to the first CR/LF (or end of file if it is encountered) and store the result in "$in.string". When the end of file is reached, V+ error number –504 "Unexpected end of file" is generated. The IOSTAT() function must be used to recognize this error and halt reading of the file:

```
DO
     READ (dlun) $in.string
     TYPE $in.string
UNTIL IOSTAT(dlun) == -504
```

The GETC function reads the file byte by byte if you want to examine individual bytes from the file (or if the file is not delimited by CR/LFs).

Detaching

When a disk logical unit is detached, any disk file that was open on that unit is automatically closed. However, error conditions detected by the close operation may not be reported. Therefore, it is good practice to use the FCLOSE instruction to close files and to check the error status afterwards. FCLOSE ensures that all buffered data for the file is written to the disk, and updates the disk directory to reflect any changes made to the file. The DETACH instruction frees up the logical unit. The following instructions close a file and detach a disk LUN:

```
FCLOSE (dlun)
     IF IOSTAT(dlun) THEN
          TYPE $ERROR(IOSTAT(dlun))
     END
DETACH (dlun)
```

When a program completes normally, any open disk files are automatically closed. If a program stops abnormally and execution will not be proceeded, the KILL monitor command will close any files left open by the program.

CAUTION: While a file is open on a floppy disk, do not replace the floppy disk with another disk or data may be lost and the new disk may be corrupted.

Disk I/O Example

The following example creates a disk file, writes to the file, closes the file, reopens the file, and reads back its contents:

```
AUTO dlun, i
AUTO $file.name

$file.name = "data.tst"

; Attach to a disk logical unit

ATTACH (dlun, 4) "DISK"
IF IOSTAT(dlun) < 0 GOTO 100

; Open a new file and check status

FOPENW (dlun) $file.name
IF IOSTAT(dlun) < 0 GOTO 100

; Write the text

FOR i = 1 TO 10
     WRITE (dlun) "Line "+$ENCODE(i)
     IF IOSTAT(dlun) < 0 GOTO 100
END

; Close the file

FCLOSE (dlun)
IF IOSTAT(dlun) < 0 GOTO 100

; Reopen the file and read its contents

FOPENR (dlun) $file.name
IF IOSTAT(dlun) < 0 GOTO 100

READ (dlun) $txt        ;Get first line from file
WHILE IOSTAT(dlun) > 0 DO
     TYPE $txt
     READ (dlun) $txt
END                     ;End of file or error
```

```
    IF (IOSTAT(dlun) < 0) AND (IOSTAT(dlun) <> -504) THEN
100      TYPE $ERROR(IOSTAT(dlun))    ;Report any errors
    END

    FCLOSE (dlun)                     ; Close the file
    IF IOSTAT(dlun) < 0 THEN
         TYPE $ERROR(IOSTAT(dlun))
    END

    DETACH (dlun)                     ; Detach the LUN
```

8.7 Advanced Disk Operations

This section introduces additional parameters to the FOPEN_ instructions. See the descriptions of the FOPEN_ instructions in the *V+ Language Reference Guide* for details.

Variable-Length Records

The default disk file access mode is "variable-length" record mode. In this mode, records can have any length (up to a maximum of 512 bytes) and can cross the boundaries of 512-byte sectors. The end of a record is indicated by a Line-Feed character (ASCII 10). Also, the end of the file is indicated by the presence of a Ctrl+Z character (26 decimal) in the file. Variable-length records should not contain any internal Line-Feed or Ctrl+Z characters as data. This format is used for loading and storing V+ programs, and is compatible with the IBM PC standard ASCII file format.

Variable-length record mode is selected by setting the record length parameter in the FOPEN_ instruction to zero, or by omitting the parameter completely. In this mode, WRITE instructions automatically append Return (ASCII 13) and Line-Feed characters to the output data—which makes it a complete record. If the "/S" format control is specified in an output specification, no Return/Line-Feed is appended. Then any subsequent WRITE will have its data concatenated to the current data as part of the same record. If the "/Cn" format control is specified, "n" Return/Line-Feeds are written, creating multiple records with a single WRITE.

When a variable-length record is read using a READ instruction, the Return/Line-Feed sequence at the end is removed before returning the data to the V+ program. If the GETC function is used to read from a disk file, **all** characters are returned as they appear in the file—including Return, Line-Feed, and Ctrl+Z characters.

Fixed-Length Records

In fixed-length record mode, all records in the disk file have the same specific length. Then there are no special characters embedded in the file to indicate where records begin or end. Records are contiguous and may freely cross the boundaries of 512-byte sectors.

Fixed-length record mode is selected by setting the record length parameter in the FOPEN_ instruction to the size of the record, in bytes. WRITE instructions then pad data records with zero bytes or truncate records as necessary to make the record length the size specified. No other data bytes are appended, and the "/S" format control has no effect.

In fixed-length mode, READ instructions always return records of the specified length. If the length of the file is such that it cannot be divided into an even number of records, a READ of the last record will be padded with zero bytes to make it the correct length.

Sequential-Access Files

Normally, the records within a disk file are accessed in order, from the beginning to the end, without skipping any records. Such files are called "sequential files." Sequential-access files may contain either variable-length or fixed-length records.

Random-Access Files

In some applications, disk files need to be read or written in a non-sequential or "random" order. V+ supports random access only for files with fixed-length records. Records are numbered starting with 1. The position of the first byte in a random-access record can be computed by:

```
byte_position = 1 + (record_number - 1) * record_length
```

Random access is selected by setting the random-access bit in the mode parameter of the FOPEN_ instruction. A non-zero record length must also be specified.

A specific record is accessed by specifying the record number in a READ or WRITE instruction. If the record number is omitted, or is zero, the record following the one last accessed is used (see the FOPEN_ description in the *V+ Language Reference Guide*).

> **NOTE:** Logically, each disk file appears to be simply a sequence of bytes. These bytes are interpreted as grouped into records according to the manner in which the file was opened. Files do not contain record format information, so any file can be opened in any record mode. (Thus, it is the programmer's responsibility to make sure files are read with the same record format as was used to create the file.)

Buffering and I/O Overlapping

All physical disk I/O occurs as 512-byte sector reads and writes. On input, records are unpacked from the sector buffer, and additional sectors are read as needed to complete a record. To speed up read operations, V+ automatically issues a read request for the next sector while it is processing the current sector. This request is called a "pre-read." Pre-read is selected by default for both sequential-access and random-access modes. It can be disabled by setting a bit in the mode parameter of the FOPEN_ instruction. If pre-reads are enabled, opening a file for read access immediately issues a read for the first sector in the file.

Pre-read operations may actually degrade system performance if records are accessed in truly random order, since sectors would be read that would never be used. In this case, pre-reads should be disabled and the FSEEK instruction should be used to initiate a pre-read of the next record to be used.

The function "IOSTAT(lun, 1)" returns the completion status for a pending pre-read or FSEEK operation.

On output, records are packed into sector buffers and written after the buffers are filled. If "no-wait" mode is selected for a write operation by using the "/N" format control, the

WRITE instruction does not wait for a sector to be written before allowing program execution to continue.

In random-access mode, a sector buffer is not normally written to disk until a record not contained in that buffer is accessed. The FEMPTY instruction empties the current sector buffer by immediately writing it to the disk.

A file may be opened in non-buffered mode, which is MUCH SLOWER than normal buffered mode, but it guarantees that information that is written will not be lost due to a system crash or power failure. This mode was intended primarily for use with log files that are left opened over an extended period of time and intermittently updated. For these types of files, the additional (significant) overhead of this mode is not so important as the benefit.

When a file is being created, information about the file size is not stored in the disk directory until the file is closed. Closing a file also forces any partial sector buffers to be written to the disk. Note that aborting a program does not force files associated with it to be closed. The files are not closed (and the directory is not updated) until a KILL command is executed, or until the aborted program is executed again.

CAUTION: To preserve newly written data, do not remove a floppy disk from the drive until you are sure the file has been closed.

Disk Commands

There are several disk-oriented monitor commands that do not have a corresponding program instruction. The FCMND instruction must be used to perform the following actions from within a program:

- Rename a file
- Format a disk
- Create a subdirectory
- Delete a subdirectory

The MCS instruction can be used to issue an FCOPY command from within a program.

FCMND is similar to other disk I/O instructions in that a logical unit must be attached and the success or failure of the command is returned via the IOSTAT real-valued function.

The FCMND instruction is described in detail in *V+ Language Reference Guide*.

Accessing the Disk Directories

The V+ directory structure is identical to that used by the IBM PC DOS operating system (version 2.0 and later). For each file, the directory structure contains the file name, attributes, creation time and date, and file size. Directory entries may be read after successfully executing an FOPEND instruction.

Each directory record returned by a READ instruction contains an ASCII string with the information shown in Table 8-1.

Table 8-1**. Disk Directory Format**

Byte	Size	Description
1-8	8	ASCII file name, padded with blanks on right
9	1	ASCII period character (46 decimal)
10-12	3	ASCII file extension, padded with blanks on right
13-20	8	ASCII file size, in sectors, right justified
21	1	ASCII space character (32 decimal)
22-28	7	Attribute codes, padded with blanks on right
29-37	9	File revision date in the format “dd-mmm-yy”
38	1	ASCII space character (32 decimal)
39-46	8	File revision time in the format “hh:mm:ss”

The following characters are possible in the file attribute code field of directory entries:

Character	Meaning
D	Entry is a subdirectory
L	Entry is the volume label (not supported by V+)
P	File is protected and cannot be read or modified
R	File is read-only and cannot be modified
S	File is a system file

The attribute field is blank if no special attributes are indicated.

The file revision date and time fields are blank if the system date and time had not been set when the file was created or last modified. (The system date and time are set with the TIME monitor command or program instruction.)

8.8 Serial Line I/O

The V+ controller has several serial lines that are available for general use. This section describes how these lines are used for simple serial communications. To use a serial line for a special protocol such as DDCMP and Kermit (described later in this chapter), the line must be configured using the Adept controller configuration utility program.[1]

I/O Configuration

In addition to selecting the protocol to be used, the Adept controller configuration program allows the baud rate and byte format for each serial line to be defined. Once the serial line configuration is defined on the V+ system boot disk, the serial lines are set up automatically when the V+ system is loaded and initialized. After the system is running, the FSET instruction can be used to reconfigure the serial lines. The following byte formats are available:

- Byte data length of 7 or 8 bits, not including parity
- One or two stop bits
- Parity disabled or enabled
- Odd or even parity (adds 1 bit to byte length)

The following baud rates are available:

110, 300, 600, 1200, 2400, 4800, 7200, 9600, 19200, 38400

In addition, V+ provides automatic buffering with optional flow control for each serial line. The I/O configuration program can be used to enable output flow control with which V+ recognizes Ctrl+S (19 decimal) and Ctrl+Q (17 decimal) and uses them to suspend and resume, respectively, serial line output. The configuration program can also enable input flow control, with which V+ generates Ctrl+S and Ctrl+Q to suspend and resume, respectively, input from an external source. With Ctrl+S and Ctrl+Q flow control disabled, all input and output is totally transparent, and all 8-bit data bytes can be sent and received.

Serial lines may also be configured to use hardware modem control lines for flow control. (The RTS/CTS lines must be installed in the modem cable—standard modem cables often leave these lines out.) See the *Adept MV Controller User's Guide* for pin assignments.

Attaching/Detaching Serial I/O Lines

Serial lines must be attached before any I/O operations can take place. Note that only one control program task can be attached to a single serial line at any one time. All other attachment requests will queue or fail, depending on the setting of the mode parameter in the ATTACH instructions.

Attaching or detaching a serial line automatically stops any output in progress and clears all input buffers. Serial lines are not automatically detached from a program unless it completes with success, so it is possible to single-step through a program or proceed from a PAUSE instruction without loss of data.

[1] The controller configuration utility is on the Adept Utility Disk in the file CONFIG_C.V2.

Input Processing

Input data is received by V+ according to the byte format specified by the I/O configuration program. The size of the buffer can be set with the CONFIG_C utility program. Data errors such as parity or framing errors are also buffered and are returned in the proper order.

The possible data errors from the serial input lines are:

–522	*Data error on device*
	A data byte was received with incorrect parity, or the byte generated a framing error.
–524	*Communications overrun*
	Data bytes were received after the input buffer was full, or faster than V+ could process them.
–526	*No data received*
	If data is expected, continue polling the serial line.
–504	*Unexpected end of file*
	A BREAK was received from the remote device

Serial line input data is normally read using the GETC function, since it allows the most flexible response to communications errors. The READ instruction also can be used provided that input data is terminated by a Line-Feed character (10 decimal).

V+ does not support input echoing or input line editing for the serial lines.

Output Processing

All serial line output is performed using the WRITE instruction. All binary data (including NULL characters) is output without conversion. If the serial line is configured to support parity, a parity bit is automatically appended to each data byte.

By default, the WRITE instruction appends a Return character (13 decimal) and a Line-Feed character (10 decimal) to each data record unless the "/S" format control is specified in the instruction parameter list.

If output flow control is enabled and output has been suspended by a Ctrl+S character from the remote device, a WRITE request may wait indefinitely before completing.

Serial I/O Examples

The first example attaches to a serial line and performs simple WRITEs and READs on the line:

```
.PROGRAM serial.io()

; ABSTRACT: Example program to write and read lines of text to and
;   from serial port 1 on the SIO module.

        AUTO slun     ;Logical unit to communicate to serial port
        AUTO $text

; Attach to a logical unit(open communications path to serial port)

        ATTACH(slun, 4) "SERIAL:1"
        IF IOSTAT(slun) < 0 GOTO 100

; Write text out to the serial port

        WRITE(slun) "Hello there! "
        IF IOSTAT(slun) < 0 GOTO 100

; Read a line of text from the serial port. The incoming line of
; text must be terminated by a carriage return and line feed. The
; READ instruction will wait until a line of text is received.

        READ(slun) $text
        IF IOSTAT(slun) < 0 GOTO 100

; Display any errors

100     IF(IOSTAT(slun) < 0) THEN
             TYPE IOSTAT(slun), " ", $ERROR(IOSTAT(slun))
        END

        DETACH(slun)  ;Detach from logical unit

.END
```

The next example reads data from a serial line using the GETC function with no-wait mode. Records that are received are displayed on the terminal. In this program, data records on the serial line are assumed to be terminated by an ETX character, which is not displayed. An empty record terminates the program.

```
.PROGRAM display()

; ABSTRACT: Monitor a serial line and read data when available
```

```
        AUTO $buffer, char, done, etx, ienod, line

        etx = 3                     ;ASCII code for ETX character
        ienod = -526                ;Error code for no data

        ATTACH (line, 4) "SERIAL:1"
        IF IOSTAT(line) < 0 GOTO 90  ;Check for errors

        $buffer = ""                ;Initialize buffer to empty
        done = FALSE                ;Assert not done

        DO
             CLEAR.EVENT
             c = GETC(line, 1)      ;Read byte from the ser. line
             WHILE c == ienod DO    ;While there is no data...
                  WAIT.EVENT 1      ;Wait for an event
                  CLEAR.EVENT
                  c = GETC(line, 1) ;Read byte from the ser. line
             END

             IF c < 0 GOTO 90       ;Check for errors

             IF c == etx THEN       ;If ETX seen...
                  TYPE $buffer, /N  ;Type buffer
                  done = (LEN($buffer) == 0) ;Done if buffer
                                             ; length is 0
                  $buffer = ""      ;Set buffer to empty
             ELSE
                  $buffer = $buffer+$CHR(c)  ;Append next byte
                                             ; to buffer
             END

        UNTIL done                  ;Loop until empty buffer seen

        GOTO 100                    ;Exit

90      TYPE "SERIAL LINE I/O ERROR: ", $ERROR(IOSTAT(line))
        PAUSE

100     DETACH (line)
        RETURN
.END
```

8.9 DDCMP Communication Protocol

DDCMP is a rigorous protocol that automatically handles the detection of errors and the retransmission of messages when an error occurs. (The name stands for Digital Data Communications Message Protocol.) It is used in Digital Equipment Corporation's computer network DECnet. DDCMP is readily available for public use, and software packages that implement this protocol are available from Digital Equipment Corporation (DEC).[1]

DDCMP makes use of one or more of the general-purpose USER serial lines. To use a serial line for DDCMP, it must be configured using the Adept I/O configuration program. (The configuration program is on the Adept Utility Diskette in the file CONFIG_C.V2.)

The Adept implementation of DDCMP does not support maintenance messages or multi-drop lines. In all other respects it is a full implementation of the protocol.

This section is not intended to be a thorough description of DDCMP. Refer to the DEC DDCMP manual for more details on protocol operation and implementation.[2]

General Operation

All messages transmitted by DDCMP are embedded in a packet that includes sequence information and check codes. Upon receipt, a message packet is checked to verify that it is received in sequence and without transmission errors.

To initiate communications, a system sends special start up messages until the proper acknowledgement is received from the remote system. This handshaking guarantees that both sides are active and ready to exchange data packets. If a start request is received after the protocol is active, it means that a system has stopped and restarted its end of the protocol, and an error is signaled to the local system.

Once the protocol is active, each transmitted message is acknowledged by the remote system, indicating that it was received correctly or requesting retransmission. If a message is not acknowledged after a certain time, the remote system is signaled and a retry sequence is initiated. If a message is not sent correctly after a number of retries, DDCMP stops the protocol and signals an error to the local system.

---

[1] For example, for computer systems with the DEC RSX-11M, RSX-11M-PLUS, and RSX-11S operating systems, DLX-11 is a compatible DDCMP handler available from DEC. This software can be purchased as "RSX DLX-11 V1.0" (reference *RSX DLX-11 User's Guide,* DEC order number AA-K142A-TC).

[2] Reference "DECnet Digital Network Architecture, Digital Data Communications Message Protocol (DDCMP) Specification," Version 4.0, March 1, 1978. Digital Equipment Corporation order number AA-D599A-TC.

Table 8-2 shows the standard DDCMP NAK reason codes generated by the Adept implementation of DDCMP.

Table 8-2. **Standard DDCMP NAK Reason Codes**

Code	Description
1	Check code error in data header or control message
2	Check code error in data field
3	REP response with NUM in REP <> R
8	Buffer temporarily unavailable for incoming data
9	Bytes lost due to receiver overrun
16	Message too long for buffer
17	Header format error (but check code was okay)

Attaching/Detaching DDCMP Devices

An ATTACH request initiates the DDCMP protocol for the specified logical unit. The attach will not complete until the remote system also starts up the protocol and acknowledges the local request. There is no time-out limit for start up, so the attach request can wait indefinitely. For applications that service multiple lines, “no-wait” ATTACH mode can be used, and the logical unit for each line can be polled with the IOSTAT function to detect when the remote system has started.

A DETACH request stops the protocol, flushes any pending input data, and deactivates the line. Any data received on the line is ignored.

Input Processing

When the protocol is active, received DDCMP data messages are stored in internal data buffers and acknowledged immediately. The maximum input message length is 512 bytes. The total number of data buffers (shared by all the DDCMP serial lines) is initially 10. The Adept controller configuration program (”CONFIG_C”) can be used to change the number of buffers allocated for use by DDCMP.

Once all the DDCMP buffers are full, additional data messages are rejected with negative acknowledge (NAK) reason #8 (Buffer temporarily unavailable). It is the user’s responsibility to limit the input data flow using a higher-level protocol on the remote system.

Input data is accessed via the V+ READ instruction. Each READ instruction returns the contents of the next data buffer. If no received data is available, the read will not complete until a data message is received. No-wait READ mode can be used for reading; the serial line can be polled using the function IOSTAT(lun, 1) to detect when the read is completed. Keep in mind that the DDCMP acknowledge was sent when the data was originally received and buffered, not when the READ instruction is executed.

Output Processing

Output on a DDCMP line is performed using the V+ WRITE instruction. Each WRITE instruction sends a single data message with a maximum length of 512 bytes. The write request does not complete until the remote system acknowledges successful receipt of the message. Retransmission because of errors is handled automatically without any action required by the V+ program.

If the no-wait format control (/N) is specified in the format list for the WRITE instruction, V+ processing continues without waiting for the write to complete. Like other output requests, a second write issued before the first has completed will force the V+ program to wait for the first write to complete. The IOSTAT(lun,3) function can be used to determine whether or not a no-wait write has completed.

> **NOTE:** A WRITE instruction automatically appends a Return character (13 decimal) and Line-Feed character (10 decimal) to the data message, unless the "/S" format control is specified.

Protocol Parameters

Certain parameters can be set to control the operation of DDCMP. These parameters are set with the V+ FCMND instruction. The following parameters can be set:

1. Time before message confirmation or retransmission is attempted. An acknowledge request must have been received before this period of time, or a time-out occurs. The default value is 3 seconds. It can be set to any value from 1 to 255 seconds.
2. Number of successive time-outs before an unrecoverable error is signaled, halting the protocol and aborting I/O requests. The default value is 8. It can be set to any value from 1 to 255.
3. Number of successive negative acknowledge (NAK) packets that can be received before an unrecoverable error is signaled, halting the protocol and aborting I/O requests. The default value is 8. It can be set to any value from 1 to 255.

The FCMND instruction to set the parameters is as follows (see *V+ Language Reference Guide* for more information on the FCMND instruction):

```
FCMND(lun, 501)$CHR(time.out)+$CHR(time.retry)+$CHR(nak.retry)
```

where

`lun`	is the logical unit number for the serial line
`time.out`	is the time-out interval, in seconds
`time.retry`	is the successive time-out maximum
`nak.retry`	is the successive NAK maximum

For example, the instruction

```
FCMND (lun, 501) $CHR(2)+$CHR(20)+$CHR(8)
```

specifies a time-out interval of 2 seconds, with a maximum of 20 time-outs and 8 NAK retries.

Status

The status of all DDCMP lines can be determined with the V+ NET monitor command, which creates a dynamic display of DDCMP activity. See *V+ Operating System Reference Guide* for a description of the NET command.

8.10 Kermit Communication Protocol

The Kermit protocol is an error-correcting protocol for transferring sequential files between computers over asynchronous serial communication lines. This protocol is available as an option to the Adept V+ system.

Kermit is non-proprietary and was originally developed at Columbia University. Computer users may copy Kermit implementations from one another, or they may obtain copies from Columbia University for a nominal charge.[1]

The following information is not intended to be a thorough description of Kermit and its use. You should refer to the *Kermit User Guide* and the *Reference Kermit Protocol Manual* (both available from Columbia University) for more details on implementation and operation of the Kermit protocol.

The Adept implementation of Kermit can communicate only with a "server" (see the *Kermit User Guide* for a definition of terms). The following material describes use of Kermit from the V+ system. In addition to this information, you will need to know how to perform steps on your computer to initiate the Kermit protocol and access disk files.

When the V+ implementation of the Kermit protocol is enabled, it makes use of one of the general-purpose USER serial lines on the Adept system controller. For a serial line to be used with Kermit, the line must have been configured using the Adept controller configuration program.[2]

Starting a Kermit Session

This section will lead you through the steps involved with initiating a Kermit file transfer session using Kermit with the V+ system. The term "remote system" is used in this discussion to refer to the computer system that is to be accessed with Kermit.

---

[1] Kermit documentation and software are available from:
Kermit Distribution
Columbia University Center for Computing Activities
612 West 115th Street
New York, NY 10025 (USA)

[2] Only one line can be configured at any one time for use with Kermit. The controller configuration program is on the Adept Utility Diskette in the file CONFIG_C.V2.

> **NOTE:** The following information should be considered an example. The specific details may not be correct for the computer system you are accessing with Kermit.

The first step is to start up a Kermit server on the remote system. One way to do this is to go into pass-through mode on the V+ system by typing the monitor command:

```
PASSTHRU KERMIT
```

The system terminal is now connected directly to the serial line to the remote system: Anything you type at the system terminal (except Ctrl+C and Ctrl+P) will be sent directly to the remote system.

If you cannot get any response from the remote system at this point, there is probably a problem with the serial line connection. A common problem is a mismatch of baud rates or other communication characteristics, or a bad serial line connection. Previous experience is helpful in solving such problems.

Once you are able to communicate with the remote system, you may have to log onto the remote system. Then, after you have reached the point of being able to enter commands to the system, the Kermit program may be started simply by typing:

```
KERMIT
```

or a similar command appropriate to the operating system of the remote computer.

The Kermit program should start up in its command mode, with a prompt such as:

```
C-Kermit>
```

You may then enter commands directly to the Kermit program. For example, you might want to enter commands to initialize various parameters in preparation for communication with the V+ Kermit. For instance, you may type:

```
SET FILE TYPE TEXT
```

to initialize the remote file type to ASCII. (The actual syntax needed for these commands will depend on the remote system. Refer to that system's user guide. Most Kermit programs are equipped with help facilities that can be invoked by typing "HELP" or a question mark ["?"].)

After successfully initializing the desired parameters, the Kermit server should be started by typing:

```
SERVER
```

The remote server should start up and type a short message about basic server usage. This message may not be applicable to use of Kermit communications with the V+ system. Whenever the instructions for handling and terminating the server differ from those in this manual, the instructions in this manual should be followed.

At this point, you should "escape back" to the (local) V+ system by typing a Ctrl+C to terminate the PASSTHRU command.

> **NOTE:** A Ctrl+C may be typed at any time while in PASSTHRU mode to escape back to the local system. This implies that you will not be able to send a Ctrl+C to the remote system. If the remote system uses Ctrl+C for special purposes (for example, the DEC VAX/VMS system uses it to interrupt operations), you will have to use some other means to achieve those special purposes.

Most Kermit servers cannot be aborted or terminated, except by a special communication packet. In order to terminate the remote server when communicating with a V+ system, you must go into PASSTHRU mode as described earlier. Then, when a Ctrl+P is typed, a special packet of information is sent to the remote server that causes it to terminate. After this is achieved, the remote Kermit program should return to command mode and display its command prompt. You may then exit Kermit and log off the remote system.

File Access Using Kermit

After the remote Kermit server has been initiated, you are ready to use the Kermit line for file access. In general, to access a file via Kermit with the V+ system, all you have to do is specify the "KERMIT>" physical device in a normal V+ file-access command or instruction. For example, the command:

```
LOAD K>file_spec
```

will load (from the remote system) the programs or data contained in the specified file. The file specification may be a simple file name, or it may contain device and directory information. The actual interpretation of the file specification depends on the remote Kermit server, as well as the type of remote system being used.

You may also use the V+ DEFAULT command to define the default disk device to be the Kermit line. That is, for example, you can enter:

```
DEFAULT = K>directory/
```

In this command, "K>" tells the V+ system it should access the Kermit device (when the local disk device is not explicitly specified), and "directory" represents directory information to be used as the default in subsequent file specifications.

After the above DEFAULT command is entered, the command:

```
LOAD file_name
```

would load a program or data file from the Kermit line.

It is also possible for a V+ program to READ and WRITE to remote sequential files over the Kermit line. To do that, the program has to perform the following steps:

1. ATTACH a disk logical unit, specifying the physical device "KERMIT" (explicitly or via the current default).

   > **NOTE:** Only one logical unit in the entire V+ system can be attached to the "KERMIT" physical device at any one time. An attempt to perform a second attachment will result in the error "*Device not ready*".

2. FOPEN_ the desired file on that logical unit (if the file is open in fixed-length-record mode as long as the length is less than about 90).
3. READ or WRITE variable-length records using that logical unit.

The following V+ commands and instructions can be used to access files with Kermit:

FCOPY	FOPENR	STOREL	VLOAD[1]
FDELETE	FOPENW	STOREP	VSTORE[1]
LOAD	FOPEND	FDIRECTORY	
FLIST	STORER	STORE	STORES

Binary files

Disk files created by the V+ system are called ASCII files, because the files contain only ASCII characters. V+ application programs (and other computers) can create non-ASCII disk files, which contain information that is not interpreted as ASCII characters. Such files are often called “binary” files.

When Kermit is transferring normal text (ASCII) files, the file contents are not adversely affected if the eighth bit of a byte is corrupted. For example, the serial line hardware would affect the eighth bit if parity checking is enabled, since that bit is used for the parity information.

However when binary files need to be transferred, the eighth bit of each byte must be preserved. Thus, the serial line parity must be set to “no parity” (that is, the serial ports on both the V+ system and the remote system must be set). Also, the Kermit “file mode” must be set to “binary”.

The parity mode for the V+ serial ports is set with the Adept controller configuration program (CONFIG_C). You may be able to set the modes on the remote system by performing the following steps:[2]

1. Go into PASSTHRU mode at the V+ system terminal.
2. Enter a command to the remote system to exit the Kermit program (it may first be necessary to terminate the server by typing Ctrl+P).
3. Enter a command to the remote system to set the terminal mode to “no parity”.
4. Enter a command to the remote system to restart the Kermit program.
5. Enter a command to the remote Kermit to set its file mode to “binary”. For example

   ```
   SET FILE TYPE BINARY
   ```

6. Enter a command to Kermit to start the remote server.
7. Type Ctrl+C to escape back to the (local) V+ system.

---

[1] VLOAD and VSTORE can be used with Kermit only in “binary” mode.
[2] The specific commands for the remote system will depend on the system you are using.

When a binary file is accessed over the Kermit line, the file specified to V+ must have a "/B" qualifier. For example, the following command will copy the file "REMOTE.DAT" from the Kermit line to the local disk drive "A":

```
FCOPY A:local.dat = K>remote.dat/B
```

> **NOTE:** If the default setting for the remote system's serial line is other than "no parity", and there is no way you can change that setting, it will not be possible to successfully transfer binary files using Kermit. An ASCII file may be accessed as a binary file, but not vice versa. A file that is transferred back and forth over the Kermit line must be transferred in the same file mode each time. For example, if a file is copied in binary mode from the remote system to the V+ system, then it must be copied back to the remote system in binary mode in order to preserve the file contents.

Kermit Line Errors

The error "*Nonexistent file*" is common when using Kermit. This error could mean any of several things, in addition to the inability to find the desired file on the remote system (the command "FDIR K>" will verify the contents of a remote directory). The transactions over the Kermit line are generally considered to be file transfers. When the V+ system tries to start a file operation, the local Kermit driver generally tries to "open" a file on the remote server. If this operation fails, V+ returns the error "*Nonexis-tent file*". Among the things that could possibly cause this error are: mismatched line settings (like baud rate and parity), unexpected server state (the server didn't terminate the previous transaction as expected), the server was not started correctly, or the file may really not exist.

> **NOTE:** When an error occurs that is associated with the use of Kermit, it sometimes helps to perform the following steps to make sure the remote server is in a known state: (1) enter PASSTHRU mode, (2) stop the remote server by typing Ctrl+P several times, and (3) restart the remote server. If a Kermit file access is aborted by the user (for example, Ctrl+C is typed to abort a V+ monitor command), it may take five seconds for the abort request to be processed.

V+ System Parameters for Kermit

Two V+ system parameters are provided for setting communication parameters for the Kermit protocol.

The parameter KERMIT.TIMEOUT sets the amount of time that the remote server is to wait for a response from the V+ system before the remote server declares a time-out error and retransmits its previous message. This parameter should be set to a high value (less than or equal to 95 seconds) when V+ READ or WRITE instructions performed on the Kermit line are far apart. That is, when there are long pauses between disk requests. (This can occur, for example, when the V+ program is being executed in single-step mode with the program debugger.)

The parameter KERMIT.RETRY is the number of errors and retransmissions that are allowed by the local V+ Kermit. When this number of errors is exceeded, the error "*Too many network errors*" will occur. When this parameter is set to a large value (less than or equal to 1000), the equivalent parameter for the remote server must be set to the same value. Otherwise, the settings will not be effective.

8.11 Summary of I/O Operations

Table 8-3 summarizes the V+ I/O instructions:

Table 8-3. **System Input/Output Operations**

Keyword	Type	Function
AIO.IN	RF	Read a channel from one of the analog IO boards.
AIO.OUT	PI	Write to a channel on one of the analog IO boards.
AIO.INS	RF	Test whether an analog input or output channel is installed.
ATTACH	PI	Make a device available for use by the application program.
BITS	PI	Set or clear a group of digital signals based on a value.
BITS	RF	Read multiple digital signals and return the value corresponding to the binary bit pattern present on the signals.
$DEFAULT	SF	Return a string containing the current system default device, unit, and directory path for disk file access.
DETACH	PI	Release a specified device from the control of the application program.
DEVICE	PI	Send a command or data to an external device and, optionally, return data back to the program. (The actual operation performed depends on the device referenced.)
DEVICE	RF	Return a real value from a specified device. The value may be data or status information, depending upon the device and the parameters.
DEVICES	PI	Send commands or data to an external device and optionally return data. The actual operation performed depends on the device referenced.
FCLOSE	PI	Close the disk file, graphics window, or graphics icon currently open on the specified logical unit.
FCMND	PI	Generate a device-specific command to the input/output device specified by the logical unit.
FEMPTY	PI	Empty any internal buffers in use for a disk file or a graphics window by writing the buffers to the file or window if necessary.
FOPENR	PI	Open a disk file for read-only.
FOPENW	PI	Open a disk file for read-write.
FOPENA	PI	Open a disk file for read-write-append.
FOPEND	PI	Open a disk directory for read.
PI: Program Instruction, RF: Real-Valued Function, P: Parameter, SF: String Function		

Table 8-3. **System Input/Output Operations** (Continued)

Keyword	Type	Function
FSEEK	PI	Position a file open for random access and initiate a read operation on the specified record.
GETC	RF	Return the next character (byte) from a device or input record on the specified logical unit.
IOGET_	RF	Return a value from a device on the VME bus.
$IOGETS	SF	Return a string value from a device on the VME bus.
IOPUT_	PI	Write a value to a device on the VME bus.
IOSTAT	RF	Return status information for the last input/output operation for a device associated with a logical unit.
IOTAS	RF	Control access to shared devices on the VME bus.
KERMIT.RETRY	P	Establish the maximum number of times the (local) Kermit driver should retry an operation before reporting an error.
KERMIT.TIMEOUT	P	Establish the delay parameter that the V+ driver for the Kermit protocol will send to the remote server.
KEYMODE	PI	Set the behavior of a group of keys on the manual control pendant.
PENDANT	RF	Return input from the manual control pendant.
PROMPT	PI	Display a string on the system terminal and wait for operator input.
READ	PI	Read a record from an open file, or from an attached device that is not file oriented.
RESET	PI	Turn “off” all the external output signals.
SETDEVICE	PI	Initialize a device or set device parameters. (The actual operation performed depends on the device referenced.)
SIG	RF	Return the logical AND of the states of the indicated digital signals.
SIG.INS	RF	Return an indication of whether or not a digital I/O signal is configured for use by the system, or whether or not a software signal is available in the system.
SIGNAL	PI	Turn “on” or “off” external digital output signals or internal software signals.
TYPE	PI	Display the information described by the output specifications on the system terminal. A blank line is output if no argument is provided.

PI: Program Instruction, RF: Real-Valued Function, P: Parameter, SF: String Function

Table 8-3. **System Input/Output Operations** (Continued)

Keyword	Type	Function
WRITE	PI	Write a record to an open file, or to an attached device that is not file oriented.

PI: Program Instruction, RF: Real-Valued Function, P: Parameter, SF: String Function

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The instructions in this chapter require an Adept A-series controller.

> **NOTE:** For clarity in presenting the programming principles, examples in this chapter leave out the calls to IOSTAT() that are critical to detecting and responding to I/O errors.

9.1 Creating Windows

V+ communicates to windows through logical units, with logical unit numbers (LUNs) 20 to 23 reserved for window use. (Each task has access to its own set of four LUNs.) The basic strategy for using a window (or any of the graphics instructions) is:

1. ATTACH to a logical unit
2. FOPEN a window on the logical unit
3. Perform the window's tasks (or graphics operations)
4. FCLOSE the window
5. FDELETE the window
6. DETACH from the logical unit

ATTACH Instruction

The ATTACH instruction sets up a communications path so a window can be written to and read from. The syntax for the ATTACH instruction is:

```
ATTACH (glun, 4) "GRAPHICS"
```

glun variable that receives the number of the attached graphics logical unit. (All menus and graphics commands that take place within a window will also use **glun**.)

FOPEN Instruction

FOPEN creates a new window or reselects an existing window for input and output. When a window is created, its name is placed in the list of available windows displayed when the **adept** logo is clicked on. The simplified syntax for FOPEN is:

```
FOPEN (glun) "window_name / MAXSIZE width height"
```

glun The logical unit already ATTACHed to.

window_name The title that will appear at the top of the window. Also used to close and select the window.

width/height Specify the largest size the window can be opened to.

This instruction will give you a window with all the default attributes. See the description of FOPEN and FSET in the *V+ Language Reference Guide* for details on how to control the attributes of a window— for example, background color, size, and scrolling.

FCLOSE Instruction

FCLOSE closes a window to input and output (but does not erase it or remove it from memory). The syntax for FCLOSE is:

FCLOSE (glun)

glun The logical unit number specified in the FOPEN instruction that opened the window.

FDELETE Instruction

FDELETE removes a closed, attached window from the screen and from graphics memory. The syntax for FDELETE is

FDELETE (glun) "window_name"

glun The same values as specified in the FOPEN instruction that
window_name created the window.

DETACH Instruction

DETACH frees up a LUN for use by a subsequent ATTACH instruction. The syntax for DETACH is:

DETACH (glun)

glun The LUN specified in a previous ATTACH instruction.

Custom Window Example

This section of code will create and delete a window:

```
    AUTO glun                    ;Graphics window LUN

    ATTACH (glun, 4) "GRAPHICS"  ; Attach to a window LUN

; Open the window "Test" with a maximum size of 400 x 300 pixels

    FOPEN(glun) "Test","/MAXSIZE 400 300"

    ; Your code for processing within the window goes here; e.g:

    GTYPE (glun) 10, 10, "Hello!"

; When the window is no longer needed, close and delete the window
;   and detach from the logical unit

    FCLOSE (glun)
    FDELETE (glun) "Test"
    DETACH (glun)
```

9.2 Monitoring Events

The key to pointing-device–driven programming is an event loop. In an event loop, you wait for an "event" (from the keyboard or pointer device) and when the correct event occurs in the proper place, your program initiates some appropriate action. V+ can monitor many different events including button up, button down, double click, open window, and menu select. The example code in the following sections will use event 2, button up, and event 14, menu select. See the description of GETEVENT in the *V+ Language Reference Guide* for details on the different events that can be monitored.

The basic strategy for an event loop is:

1. Wait for an event to occur.
2. When an event is detected:
   a. If it is the desired event, go to step 3.
   b. Otherwise, return to step 1.
3. Check the data from the event array (not necessary for event 14, menu select):
   a. If it is appropriate, go to step 4.
   b. Otherwise, return to step 1.
4. Initiate appropriate action.
5. Return to step 1.

GETEVENT Instruction

The instruction that initiates monitoring of pointer device and keyboard events is GETEVENT. Its simplified syntax is:

`GETEVENT (lun) event[]`

`lun` Logical unit number of the window to be monitored.

`event[]` Array into which the results of the detected event will be stored. The value stored in **`event[0]`** indicates which event was detected.

If **`event[0]`** is 2, a button-up event was detected, in which case:

`event[1]` indicates the number of the button pressed. (For two-button devices, 2 = left button, 4 = right button. For three-button devices, 1 = left button, 2 = middle button, 4 = right button.)

`event[2]` is the X value of the pointer location of the click.

`event[3]` is the Y value of the pointer location of the click.

If **`event[0]`** is 14, a click on a menu bar selection was detected, in which case:

If **`event[1]`** is 0, a click has been made to the top-level menu bar. In this case, an FSET instruction must be executed to display the pull-down options under

the menu bar selection and **event[2]** is the number (from left to right) of the menu bar option selected.

If **event[1]** is 1, then a selection from a pull-down menu has been made and **event[2]** is the number of the pull-down option selected.

You cannot use the GETEVENT instruction to specify which events to monitor. It monitors all the events that are enabled for the window. See descriptions of the FOPEN and FSET instructions in the V^+ *Language Reference Guide* for details on using the "/EVENT" argument for enabling and disabling the monitoring of various events.

FSET Instruction

FSET is used to alter the characteristics of a window opened with an FOPEN instruction, and to display pull-down menus. We are going to describe only the use of FSET to create the top-level menu bar, create the pull-down menu selections below the top-level menu, and initiate monitoring of events. The instruction for displaying a top-level menu is:

FSET (glun) " /MENU 'item1' 'item2' ... 'item10' **"**

glun is the logical unit of the window the menu will be displayed in.

item1-item10 are the menu titles for a top-level bar menu. The items appear from left to right.

The instruction to display a pull-down menu (called when event[0] = 14 and event[1] = 0) is:

FSET (glun) "/PULLDOWN", top_level#," ' item1 ' ... ' itemn ' "

top_level# is the number of the top-level selection the pull-down menu is to appear under.

item1-itemn are the menu items in the pull-down menu. The items appear from top to bottom.

The relationship between these two uses of FSET will become clear when we actually build a menu structure.

The basic FSET instruction for monitoring menu and mouse events is:

FSET (glun) "/EVENT BUTTON MENU"

9.3 Building a Menu Structure

The strategy for implementing a menu is:

1. Declare the top-level bar menu.
2. Start a loop monitoring event 14 (menu selection).
3. When event 14 is detected, check to see if the mouse event was on the top-level bar menu or on a pull-down option.
4. If the event was a top-level menu selection, then display the proper pull-down options.
5. If the event was a pull-down selection, use nested CASE structures to take appropriate action based on the selections made to the top-level menu and its corresponding pull-down menu.

Menu Example

This code segment will implement a menu structure for a window open on “glun”:

```
; Set the top-level menu bar and enable monitoring of events

     FSET (glun) "/menu 'Menu 1' 'Menu 2' 'Menu 3'"
     FSET (glun) "/event button menu"

; Define the strings for the pull-down menus

     $menu[1] = "'Item 1-1' 'Item 1-2'"
     $menu[2] = "'Item 2-1' 'Item 2-2' 'Item 2-3’"
     $menu[3] = "'Quit'"

; Set variable for event to be monitored

     wn.e.menu = 14

; Start the processing loop

     quit = FALSE
     DO
          GETEVENT (glun) event[]
          IF event[0] == wn.e.menu THEN

; The menu event (14) has two components; a button-down component
;    corresponding to a click on a menu bar selection, and a
;    button-up component corresponding to the pull-down selection
;    made when the button is released.
;    After the first component (pointer down on the menu bar),
;    event[1] will be 0 and event[2] will have the number of the
;    menu bar selection.

; Check to see if event[1] is 0, indicating a top-level menu select

               IF event[1] == 0 THEN
```

```
; Use the value in event[2] to select a pull-down menu

                    FSET (lun) "/pulldown", event[2], $menu[event[2]]

; Else, execute the appropriate code for each menu selection

               ELSE

; If event[1] is not 0, then the button has been released on a
;    pull-down selection and:
;         event[1] will have the value of the top-level selection (menu)
;         event[2] will have the value of the pull-down selection (item)

                    menu = event[1]
                    item = event[2]

; The outer CASE structure checks the top-level menu selection
; The inner CASE structure checks the item selected from the pull-down

                    CASE menu OF
                         VALUE 1:                  ;Menu 1
                              CASE item OF
                                   VALUE 1:
                                        ;code for Item 1-1
                                   VALUE 2:
                                        ;code for Item 1-2
                              END
                         VALUE 2:                  ;Menu 2
                              CASE item OF
                                   VALUE 1:
                                        ;code for Item 2-1
                                   VALUE 2:
                                        ;code for Item 2-2
                                   VALUE 3:
                                        ;code for Item 2-3
                              END
                         VALUE 3:                  ;Menu 3
                              CASE item OF
                                   VALUE 1:
                                        quit = TRUE;time to quit
                              END
                    END ; case menu of
               END ; if event[1]
          END ; if event[0]
     UNTIL quit
```

Implementing the above code and then clicking on “Menu 2” would result in the window shown in Figure 9-1.

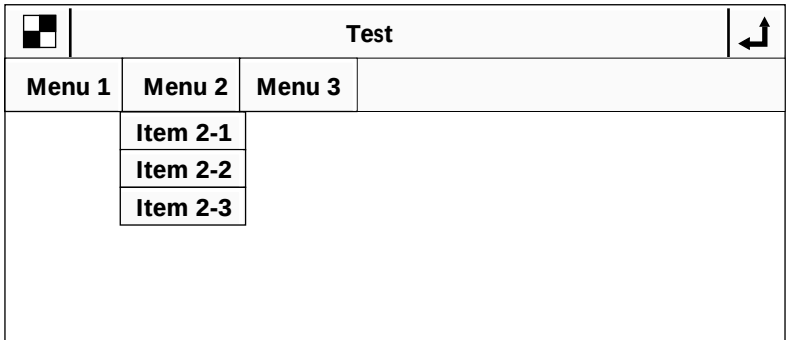

Figure 9-1. **Sample Menu**

9.4 Creating Buttons

Creating a “button” in a window is a simple matter of placing a graphic representing your button on the screen, and then looking to see if a mouse event occurred within the confines of that graphic.

GPANEL Instruction

The GPANEL instruction is useful for creating standard button graphics. The syntax for GPANEL is:

GPANEL (glun, mode**) x, y, dx, dy**

glun The logical unit of the window the button is in.

mode Is replaced with:

0 indicating a raised, ungrooved panel
2 indicating a sunken, ungrooved panel
4 indicating a raised, grooved panel
6 indicating a sunken, grooved panel

(Adding 1 to any of the mode values will fill the panel with foreground color.)

x y Coordinates of the upper left corner of the button.

dx dy Width and height of the button.

Button Example

This code segment would place a “button” on the screen and then monitor a button-up event at that button (the logical unit the button is accessing must be ATTACHed and FOPENed):

```
; Initialize monitoring of button events for a button
   FSET (glun) "/event button"
; Draw a 45x45 pixel panel at window coordinates 100,100
   GPANEL (glun, 0) 100, 100, 45, 45
; Put a label in the button
   GTYPE (glun) 102, 122, "Label"
; Declare a variable for pointer event 2 (button up)
   btn.up = 2
; Set a variable that will stop the monitoring of button events
   hit = FALSE
; Start a loop waiting for a button-up event
   DO
        GETEVENT(glun) event[]
; The status of a button event will be stored in event[0].
;  Look to see if that event was a button-up event.
        IF event[0] == btn.up THEN
; Check if the button-up event was within the button area
; The x location is in event[1], the y location in event[2]
             hit = (event[2] > 99) AND (event[2] < 146)
             hit = hit AND (event[3] > 99) AND (event[3] < 146)
        END
   UNTIL hit
; The code for reacting to a button press is placed here.
```

This code will work for a single button, but will become very unwieldy if several buttons are used. In the case of several buttons, you should place the button locations in arrays (or a two-dimensional array), and then pass these locations to a subroutine that checks if the mouse event was within the array parameters passed to it.

9.5 Creating a Slide Bar

V+ allows you to create a feature similar to the window scroll bars called “slide bars”. The syntax for a slide bar is:

```
GSLIDE (glun, mode) slide_id = x, y, len, max_pos, arrow.inc,
                                                        handle
```

glun The logical unit of the window the slide bar is to be created in.

mode is replaced with:

0 indicating a horizontal slide bar is to be created or updated.
1 indicating a slide bar is to be deleted.
2 indicating a vertical slide bar is to be created or updated.

slide_id A number that will identify the slide bar. This number is returned to the event queue so you can distinguish which slide was moved.

x y The coordinates of the top left corner of the slide bar.

len The width or height of the bar.

max_pos Specifies the maximum value the slide bar will return.

arrow_inc Specifies the increment the slide bar should register when the arrows are clicked. (The slide bar will be created with a scroll handle and scroll arrows.)

handle Specifies position the scroll handle will be in when the slide bar is created.

GSLIDE Example

We will be interested in two events when monitoring a slide bar, event 8 (slide bar pointer move) and event 9 (slide bar button up). Additional event monitoring must be enabled with the FSET instruction. “Object” must be specified to monitor slide bars and “move_b2” must be specified to monitor the dragging of the middle button.

The values returned in the GETEVENT array will be:

event[0] the pointer device event code
event[1] the ID of the slide bar (as specified by **slide_id**)
event[2] the slide bar value
event[3] the maximum slide bar value

The following code will display and monitor a slide bar:

```
; The slide bar will be in the window open on glun

     AUTO glun

; The slide bar will use events 8 and 9. A double click event will halt
;    monitoring of the slide bar

     btn.smov = 8
     btn.sup = 9
     btn.dclk = 3

; Slide bar position and start-up values

     x = 20
     y = 60
     length = 200
     max.pos = 100
     arrow_inc = 10
     handle_pos = 50

; Enable monitoring of slide bars and pointer drags

     FSET(glun) "/event object move_b2"

; Display the slide bar

     GSLIDE (glun, 0) 1 = x, y, length, max_pos, arrow_inc, handle_pos


; Begin monitoring events and take action when the slide bar is moved. Monitor
;    events until a double click is detected, then delete the slide bar

     DO
          GETEVENT(glun) event[]
          IF (event[0] == btn.smov) OR (event[0] == btn.sup) THEN

               ;Your code to monitor the slide bar value (event[2]) goes here

          END
     UNTIL event[0] == btn.dclk

; Delete the slide bar

     GSLIDE (glun, 1) 1
```

9.6 Graphics Programming Considerations

Buttons and menus can be monitored in the same window. However, the code will get complicated, and you might consider using different windows when the button and menu structure becomes complex.

Only one pull-down menu can be active at any time.

Design your windows with the following mechanical and aesthetic considerations:

- Keep your windows as simple and uncluttered as possible. Use color carefully and purposefully.
- If you are using multiple windows, use similar graphic elements so the screen elements become familiar and intuitive.
- Let the operator know what is going on. Never leave the operator in the dark as to the status of a button push or menu selection.
- Whenever possible, have your windows mimic the real world the operator is working in.

In the interest of clarity, the examples in this chapter have not been generalized. When you actually program an application, use generalized subroutine calls for commonly used code, or your code will quickly become unmanageable.

Using IOSTAT( )

The example code in this chapter leaves out critical error detection and recovery procedures. Effective application code requires these procedures. The IOSTAT function should be used to build error-handling routines for use with every ATTACH, FOPEN, FCLOSE, and FSET instruction. The syntax for using IOSTAT to check the status of I/O requests is:

`IOSTAT(lun)`

`lun` The LUN specified in the previous I/O request.

The IOSTAT function will return the following values:

1	if the last operation was successful
0	if the last operation is not yet complete
< 0	if the last operation failed, a negative number corresponding to a standard Adept error code will be returned.

The following code will check for I/O errors:

```
; Issue I/O instruction (ATTACH, FOPEN, etc.)
   IF IOSTAT(lun) < 0 THEN
        ;your code to handle the error
   END
```

```
; The ERROR function can be used to return the text of an error
;   number. The code line is:

    TYPE $ERROR(IOSTAT(lun))
```

Managing Windows

Windows can be:

- Hidden (but not deleted)

  A hidden window is removed from the screen but not from graphics memory, and it can be retrieved at any time:

  ```
  FSET(glun) "/NODISPLAY"      ;Hide a window
  FSET(glun) "/DISPLAY"        ;Redisplay a window
  ```

- Deselected (sent behind the parent's window stack):

  ```
  FSET(glun) "/STACK -1"
  ```

- Selected (brought to the front of the window stack):

  ```
  FSET(glun) "STACK 1"
  ```

If you will not be reading events from a window, open it in write-only mode to save memory and processing time.

Only the task that opened a window in read / write mode can read from it (monitor events).

Multiple tasks can write to an open window. A second task can write to an already open window by executing its own ATTACH and OPEN for the window. The logical units' numbers need not match but the window name must be the same. If a task has the window "Test" open, other tasks can write to the window by:

```
ATTACH(lun_1, 4) "GRAPHICS"
FOPEN(lun_1) "Test /MAXSIZE 200 200 /WRITEONLY"
```

9.7 Communicating With the System Windows

The Adept system has three operating system level windows: the main window, the monitor window, and the vision window (on systems with the AdeptVision VME option).

The Main Window

You can place menu options on the top-level menu bar by opening the window "\Screen_1". For example:

```
ATTACH (glun, 2) "GRAPHICS"
FOPEN (glun) "\Screen_1 /menu 'item1' 'item2' 'item3'
```

will open the main window and place three items on the top-level menu bar. Pull-downs and event monitoring can proceed as described earlier. The instruction:

```
FSET (glun) "/menu "
```

will delete the menu items.

The Monitor Window

The monitor window can be opened in write-only mode to change the characteristics of the monitor window. For example, the following instruction will open the monitor window, disable scrolling, and disallow moving of the window:

```
FOPEN (glun) "Monitor /WRITEONLY /SPECIAL NOPOSITION NOSIZE"
```

To prevent a user from accessing the monitor window, use the instruction:

```
FOPEN (glun) "Monitor /WRITEONLY /NOSELECTABLE
```

To allow access:

```
FSET (glun) "/SELECTABLE"
```

The Vision Window

For systems equipped with the Adept Vision VME option, text or graphics can be output to the vision window, and events can be monitored in the vision window. To communicate with the vision window, you open it just as you would any other window. For the window name you must use "Vision". For example:

```
FOPEN (glun) "Vision"
```

Remember, graphics output to the vision window is displayed only when a graphics display mode or overlay is selected. When you are done communicating with the vision window, close and detach from it just as you would any other window. This will free up the logical unit, but will not delete the vision window. You can close and detach from the vision window, but you cannot delete it.

To preserve the vision system pull-down menus, open the window in write-only mode:

```
FOPEN (glun) "Vision /WRITEONLY"
```

The following example opens the vision window, writes to the vision window, and detaches the vision window:

```
.PROGRAM label.blob()

; ABSTRACT: This program demonstrates how to attach to the vision
;   window and how to use the millimeter scaling mode of the
;   GTRANS instruction to label a "blob" in the vision window.
;

    AUTO vlun

    cam = 1

; Attach the vision window and get a logical unit number

    ATTACH (vlun, 4) "GRAPHICS"
    IF IOSTAT(vlun) < 0 GOTO 100

    FOPEN (vlun) "Vision"   ;Open the vision window
    IF IOSTAT(vlun) < 0 GOTO 100

; Select display mode and graphics mode

    VDISPLAY (cam) 1, 1     ;Display grayscale frame and graphics

; Take a picture and locate an object

    VPICTURE(cam)           ;Take a processed picture

    VLOCATE(cam, 2) "?"     ;Attempt to locate an object

    IF VFEATURE(1) THEN     ;If an object was found...

         GCOLOR(vlun) 1     ;Select the color black
         GTRANS (vlun, 2)   ;Select millimeter scaling
         GTYPE(vlun) DX(vis.loc), DY(vis.loc), "Blob", 3

    ELSE                    ;Else if object was NOT found...

         GCOLOR (vlun) 3    ;Select the color red
         GTRANS(vlun, 0)    ;Select pixel scaling
         GTYPE (vlun) 100, 100,"No object found!", 3
    END

; Detach (frees up the communications path)

    DETACH (vlun)

100 IF (IOSTAT(vlun) < 0) THEN   ; Check for errors
        TYPE $ERROR(IOSTAT(vlun))
    END

.END
```

9.8 Additional Graphics Instructions

Table 9-1 lists the different graphics instructions. See the *V+ Language Reference Guide* for complete details on using these instructions.

Table 9-1. **List of Graphics Instructions**

Command	Action
GARC	Draw an arc or circle in a graphics window.
GCHAIN	Draw a chain of points.
GCLEAR	Clear an entire window to the background color.
GCLIP	Constrain the area of a window within which graphics are displayed.
GCOLOR	Set the foreground and background colors for subsequent graphics instructions.
GCOPY	Copy one area of a graphics window to another area in the window.
GFLOOD	Flood an area with foreground color.
GICON	Allows you to display icons on the screen. You can access the predefined Adept icons or use your own icons created with the Icon Editor (see the *Instructions for Adept Utility Programs*).
GLINE	Draw a line.
GLINES	Draw multiple lines.
GLOGICAL	Set the drawing mode for the next graphics instruction. Useful for erasing existing graphics and simulating the dragging of a graphic across the screen.
GPOINT	Draw a single point.
GRECTANGLE	Draw a rectangle.
GSCAN	Draw a series of horizontal lines.
GSLIDE	Create a slide bar.
GTEXTURE	Develop a texture for subsequent graphics. Set subsequent graphics to transparent or opaque.
GTRANS	Define a transformation to apply to all subsequent “G” instructions.
GTYPE	Display a text string.

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10.1 Introduction

This chapter provides an overview of strategies for programming the manual control pendant. General use of the manual control pendant is covered in the *Manual Control Pendant User's Guide*.

ATTACHing and DETACHing the Pendant

Before an application program can communicate with the MCP, the MCP must first be ATTACHed using the ATTACH instruction. The logical unit number for the MCP is 1. The following instruction will ready the MCP for communication:

```
mcp_lun = 1
ATTACH (mcp_lun)
```

When the MCP is ATTACHed, the "USER" LED on the MCP will be lit.

As with all other devices that are ATTACHed by a program, the MCP should be DETACHed when the program is finished with the MCP. The following instruction will free up the MCP:

```
DETACH (mcp_lun)
```

When the MCP has been ATTACHed by an application program, the user can interact with the pendant without putting the controller key switch in the "Pendant" position.

As with all I/O devices, the IOSTAT function should be used to check for errors after each I/O operation.

10.2 Writing to the Pendant Display

The Pendant Display

The MCP display is a 2-line, 80-character LCD display. It is written to using the WRITE instruction.

Using WRITE With the Pendant

The following instructions will display a welcome message on the two lines of the pendant display:

```
    AUTO mcp_lun                ; Pendant LUN
    AUTO $intro

    $intro = "Welcome to the MCP"
    mcp_lun = 1

; Attach the MCP, check for errors and output message
```

```
     ATTACH (mcp_lun)
     IF IOSTAT(mcp_lun) < 1 GOTO 100

     WRITE (mcp_lun) $intro
     WRITE (mcp_lun) "Instructions to follow...", /S

100  IF IOSTAT(mcp_lun) < 1 THEN      ;Report errors
         TYPE IOSTAT(mcp_lun), " ", $ERROR(IOSTAT(MCP_LUN))
     END

     DETACH(mcp_lun)
```

Notice that the second WRITE instruction uses the "/S" qualifier. This qualifier suppresses the carriage return-line feed (<CR-LF>) that is normally sent by the WRITE instruction. If this qualifier was not specified, the first line displayed would have been scrolled off the top. In section 10.4 we will detail the pendant control codes. These codes control the cursor position, the lights on the MCP, and the interpretation of MCP button presses. These codes are sent to the pendant using the WRITE instruction. The "/S" qualifier must be sent with these instructions to avoid overwriting the pendant display.

10.3 Detecting User Input

Input from the pendant can be received in two ways:

- A series of button presses from the data entry buttons can be read. The READ instruction is used for this type of input.
- A single button press from any of the buttons can be detected. These single button presses can be monitored in three different modes:
    a. The buttons can be monitored like keys on a normal keyboard.
    b. The buttons can be monitored in "toggle" mode ("on" or "off"). The state of the button is changed each time the button is pressed.
    c. The keys can be monitored in "level" mode. The state of the button is considered "on" only when the button is held down.

  The PENDANT( ) function is used to detect button presses in these modes. The KEYMODE instruction is used to set the button behavior.

Using READ With the Pendant

The READ instruction accepts input from the pendant "Data Entry Buttons" (1, 2, 3, 4, 5, 6, 7, 8, 9, 0, ., +, –). A READ instruction expects a <CR-LF> to indicate the end of data entry. On the MCP, this sequence is sent by the "REC/DONE" button (similar to the Enter or Return key on a normal keyboard). The "DEL" button behaves like the "Backspace" key on a normal keyboard. All other pendant buttons are ignored by the READ instruction. Note that the predefined function buttons are active and may be used while an attached program is waiting for input.

The instruction line:

```
READ(1) $response
```

will pause the program and wait for input from the pendant. The user must signal the end of input by pressing the "REC/DONE" button. The input will be stored in the string variable "$response". The input can be stored as a real variable, but the "+" and "–" buttons must not be used for input.

Detecting Pendant Button Presses

Individual MCP button presses are detected with the PENDANT( ) function. This function returns the number of the first acceptable button press. The interpretation of a button press is determined by the KEYMODE instruction. See the *V+ Language Reference Guide* for complete details. The basic use of these two operations is described below.

Keyboard Mode

The default mode is "keyboard". If a PENDANT( ) instruction requests keyboard input, the button number of the first "keyboard" type button pressed will be returned. See Figure 10-1 for the numbers of the buttons on the MCP. The following code will detect the first soft button pressed:

```
; Set the soft keys to keyboard mode

   KEYMODE 1,5 = 0

; Wait for a button press from buttons 1 - 5

   DO
        button = PENDANT(0)
   UNTIL button < 6
```

The arguments to the KEYMODE instruction indicate that pendant buttons 1 through 5 are to be configured in "keyboard" mode. The "0" argument to the PENDANT( ) function indicates that the button number of the first "keyboard" button pressed is to be returned.

Toggle Mode

To detect the state of a button in toggle mode, the PENDANT( ) function must specify the button to be monitored.

When a button is configured as a toggle button, its state is maintained as "on" (–1) or "off" (0). The state is toggled each time the button is pressed. If an LED is associated with the button, it is also toggled. The following code sets the "REC/DONE" button to toggle mode and waits until "REC/DONE" is pressed:

```
; Set the REC/DONE button to toggle

    KEYMODE 8 = 1

; Wait until the REC/DONE button is pressed

    DO
         WAIT
    UNTIL PENDANT(8)
```

The arguments to KEYMODE indicate that MCP button number 8 (the "REC/DONE" button) is configured as a toggle button. The argument to PENDANT() indicates that the state of MCP button 8 is to be read.

Level Mode

To detect the state of a button in level mode, the PENDANT( ) function must specify the button to be monitored.

When a button has been configured as a level button, the state of the button is "on" as long as the button is pressed. When the button is not pressed, its state is "off". The following code uses the buttons labeled "2", "4", "6", and "8" (button numbers 45, 47, 49, and 57—don't confuse the button labels with the numbers returned by the PENDANT function) to move the cursor around the terminal display. The buttons are configured as level buttons so the cursor moves as long as a button is depressed.

```
; Set the REC/DONE button to toggle
    KEYMODE 8 = 1

; Set the data entry buttons labeled "2" - "8" to level

    KEYMODE 45, 51 = 2

    DO
         IF PENDANT(49) THEN
              TYPE /X1, /S   ;Cursor right
         END
         IF PENDANT(47) THEN
              TYPE $CHR(8)   ;Cursor left (backspace)
         END
         IF PENDANT(51) THEN
              TYPE /U1, /S   ;Cursor up
         END

         IF PENDANT(45) THEN
              TYPE $CHR(12)  ;Cursor down (line feed)
         END
    UNTIL PENDANT(8)
```

Monitoring the MCP Speed Bar

The speed bar on the MCP returns a value from –128 to 127 depending on where it is being pressed. An argument of "–2" to the PENDANT( ) function will return the value of the speed bar. The following code displays the state of the speed bar.

```
; Set the REC/DONE button to toggle

    KEYMODE 8 = 1

; Display speed bar value until the REC/DONE is pressed

    DO
         WRITE(1) PENDANT(-2)
    UNTIL PENDANT(8)
```

The "Slow" button is intended to alter the value returned by the speed bar. The following code compresses the range of values returned by 50% whenever the "Slow" button is "on".

```
; Set the REC/DONE button to toggle

    KEYMODE 8 = 1

; Do until the REC/DONE button is pressed

    DO
         IF PENDANT(36) THEN
              TYPE PENDANT(-2) * 0.5
         ELSE
              TYPE PENDANT(-2)
         END
    UNTIL PENDANT(8)
```

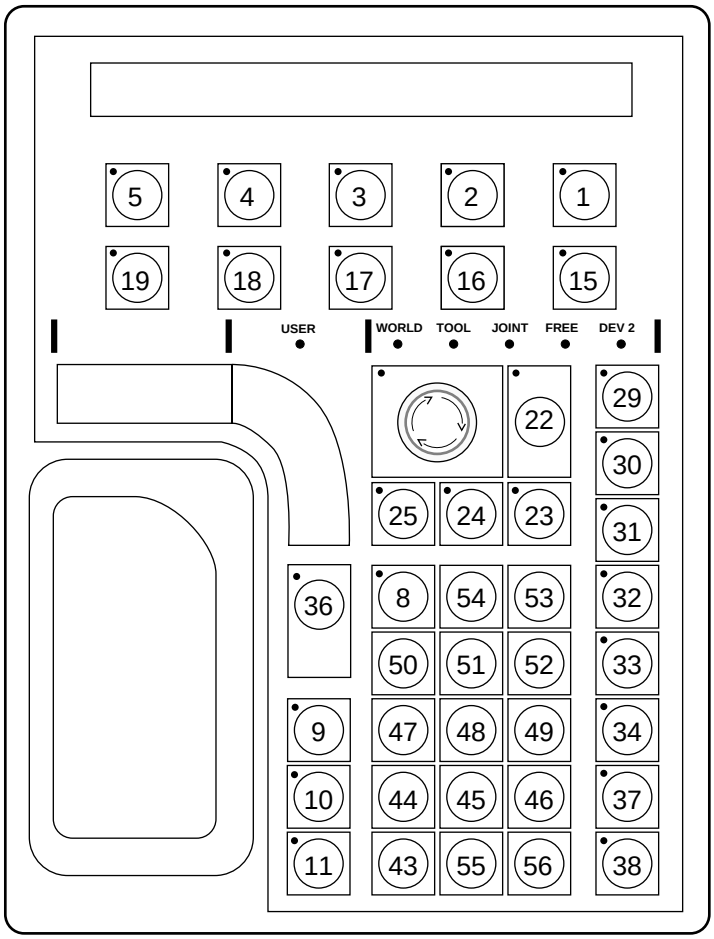

Figure 10-1. **MCP Button Map**

Reading the State of the MCP

It is good programming practice to check the state of the MCP before ATTACHing to it. The instruction:

```
cur.state = PENDANT(-3)
```

will return a value to be interpreted as follows:

1 Indicates that one of the predefined function buttons has been pressed.

2 Indicates the MCP is in background mode (not ATTACHed to an application program).

3 Indicates an error is being displayed.

4 Indicates that the MCP is in USER mode (ATTACHed to an application program).

See section 10.6 on page 203 for a program example that checks the MCP state.

10.4 Controlling the Pendant

The MCP responds to a number of control codes that affect the LCD panel, whether or not the buttons are "repeat" buttons, and the LEDs associated with the pendant buttons. The control codes are listed in Table 10-1. The control codes are sent as ASCII values using the WRITE instruction. The normal way to send control codes is to use the $CHR( ) function to convert a control code to its ASCII value.

Control Codes for the LCD Panel

To clear the display and position the cursor in the middle of the top line, issue the instruction:

```
WRITE(mcp_lun) $CHR(12), $CHR(18), $CHR(20), /S
```

"$CHR(12)" clears the pendant and places the cursor at position 1 (see Figure 10-2). "$CHR(18)" indicates that the next value received should be interpreted as a cursor location. "$CHR(20)" indicates the cursor should be placed at position 20. "/S" must be appended to the WRITE instruction or a <CR-LF> will be sent. Notice that using control code 18 allows you to position the cursor without disturbing existing text.

The following code will place the text "EXIT" in the middle of the bottom line and set the text blinking.

```
WRITE(mcp_lun) $CHR(18), $CHR(58), "EXIT", /S
WRITE(mcp_lun) $CHR(18), $CHR(58), $CHR(22), $CHR(4), /S
```

"$CHR(22)" tells the pendant to start a series of blinking positions starting at the current cursor location and extending for the number of positions specified by the next control code ("$CHR(4)"). This code will cause any text in positions 58 - 62 to blink until an instruction is sent to cancel the blinking. The following code line disables the blink positions:

```
WRITE(mcp_lun) $CHR(18), $CHR(58), $CHR(23), $CHR(4), /S
```

"$CHR(23)" tells the pendant to cancel a series of blinking positions starting at the current cursor location and extending for the number of positions specified by the next control code ("$CHR(4)").

Text can be made to blink as it is written to the display, regardless of the position the text is in. The following code writes the text "EXIT" to the middle of the bottom line, starts the "E" blinking, and then beeps the MCP:

```
WRITE(mcp_lun) $CHR(18), $CHR(58), $CHR(2), "E", /S
WRITE(mcp_lun) $CHR(3), "XIT", /S
WRITE(mcp_lun) $CHR(7), /S
```

"$CHR(2)" starts blink mode. Any characters sent to the MCP display will blink. Blink mode is canceled by "$CHR(3)". "$CHR(3)" cancels blink mode for subsequent characters; it does not cancel blinking of previously entered characters. It also does not cancel blinking of character positions set by control code 22. "$CHR(7)" causes the pendant to beep.

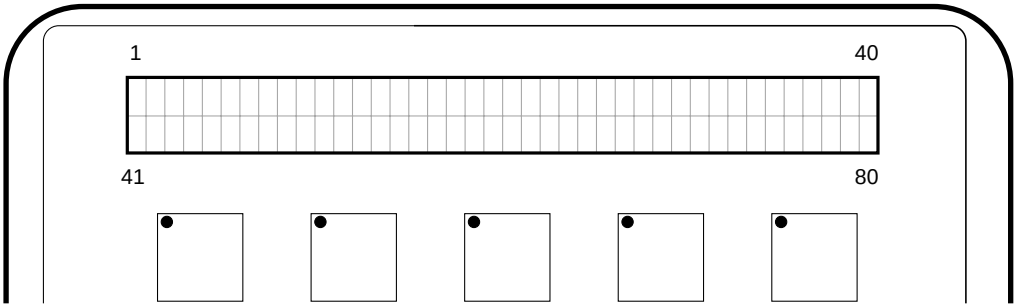

Figure 10-2. **Pendant LCD Display**

The Pendant LEDs

The LEDs on the soft buttons, the "F" buttons, and the "REC/DONE" button can be lit (either continuously or intermittently). The following code places the text "CLEAR" and "EXIT" over the first two soft buttons, lights the LED over the first soft button, and blinks the light over the second soft button:

```
WRITE(mcp_lun) $CHR(18), $CHR(41), "CLEAR", /S
WRITE(mcp_lun) $CHR(9), "EXIT", /S
WRITE(mcp_lun) $CHR(31), $CHR(5), /S
WRITE(mcp_lun) $CHR(30), $CHR(4), /S
```

"$CHR(9)" tabs the cursor to the next soft button position. "$CHR(31)" lights an LED. "$CHR(30)" starts an LED blinking. The button LED to be lit is specified in the ensuing control code. In the above example, button 5's LED is turned on and button 4's LED is set blinking. The soft buttons, "F" buttons, and REC/DONE button are the only buttons that have programmable LEDs.

Making Pendant Buttons Repeat Buttons

Pendant buttons that are configured as "keyboard" buttons are normally repeat buttons: Button presses are recorded as long as the button is held down. The repeat function can be disabled, requiring users to press the button once for each button press they want recorded. The following instruction disables the repeat option for the period (.) button:

```
WRITE(mcp_lun) $CHR(25), $CHR(55), /S
```

The repeat option is enabled with the instruction:

```
WRITE(mcp_lun) $CHR(24), $CHR(55), /S
```

Table 10-1 lists all the control codes used with the pendant.

Table 10-1. **Pendant Control Codes**

Single Byte Control Codes		
Code	**Function**	
1	(Not Used)	
2	Enable blink mode for subsequent characters	
3	Disable blink mode for subsequent characters (characters will still blink if they appear in a blinking position set by code 22)	
4	Display cursor (make the cursor visible)	
5	Hide cursor (make the cursor invisible)	
6	(Not Used)	
7	Beep	
8	Backspace (ignored if cursor is in character position 1)	
9	Tab to next soft button	
10	Line feed (move down in same position, scroll if on line 2)	
11	Vertical tab (move up in same position, do not scroll)	
12	Home cursor and clear screen (cancels any blinking positions, but does not affect “blink mode” set by code 2)	
13	Carriage return (move to column 1 of current line)	
14	Home cursor (move to character position 1)	
15	Clear from cursor position to end of line	
Double Byte Control Codes		
Code	**Function**	**Second Code**
16	(Not Used)	
17	(Not Used)	
18	Position cursor	Cursor position (1-80)
19	(Not Used)	
20	(Not Used)	
21	(Not Used)	
22	Enable blinking positions starting at current cursor location	Number of blinking positions (1-80)
23	Disable blinking positions starting at current cursor location	Number of blinking positions (1-80)
24	Enable repeat mode for button	Button number
25	Disable repeat mode for button	Button number
26	(Not Used)	
27	(Not Used)	

Table 10-1. **Pendant Control Codes** (Continued)

Code	Function	Second Code
28	Turn off pendant button LED	Light number *
29	(Not used)	
30	Start pendant button LED blinking	Light number *
31	Turn on pendant button LED	Light number *

*For soft buttons, “F” buttons, and REC / DONE button only

10.5 Auto-Starting Programs With the MCP

The "CMD" predefined function button provides three options for loading and auto-starting a program from the pendant. These three options are "AUTO START", "CMD1", and "CMD2". The program file requirements for all three options are the same:

1. The file being loaded must be on the default disk. The default disk is specified with the DEFAULT DISK command. The utility CONFIG_C can be used to specify a default disk at startup.[1] See the *Instructions for Adept Utility Programs* for details on running this utility.
2. The file name must correspond to the MCP selection. If "CMD1" is pressed, the disk file must be named CMD1.V2. If "AUTO START" is pressed, the user will be asked to input one or two digits. These digits will be used to complete the file name AUTOxx.V2. A corresponding file name must exist on the default drive.
3. A command program with the same name as the file name (minus the extension) must be one of the programs in the file. If AUTO22.V2 is loaded, the program "auto22" will be COMMANDed. See the *V+ Operating System Reference Guide* for details on command programs.

WAIT.START

Starting a robot program while the operator is in the workcell can be extremely dangerous. Therefore, Adept has installed the following safety procedure to prevent program startup while an operator is in the workcell. Before a program auto-started from the MCP will begin execution, the operator will have to leave the workcell, put the controller key switch in the terminal position, and press the "Program Start" button. The WAIT.START instruction implements this safety feature. This instruction is automatically included in any programs started with the AUTO START, CMD, CMD1, CMD2, and CALIBRATE buttons on the MCP. You should include this safety feature in any pendant routines you write that initiate monitor command programs that include robot motions. The command "WAIT.START" in a monitor command program will pause execution of a monitor command program until the key switch is correctly set and the PROGRAM START button is pressed. See the *V+ Language Reference Guide* for other uses of WAIT.START.

WARNING: For this safety feature to be effective, the optional front panel must be installed outside the workcell.

[1] The default disk is not the same as the boot drive. The boot drive is set in hardware and is used during the boot procedure to specify the drive that contains the operating system. Once the system is loaded, the default disk is the drive and path specification for loading and storing files.

10.6 Programming Example: MCP Menu

The following code implements a menu structure on the MCP. (Additionally, section A.3 presents a program example for using the MCP to teach robot locations.)

```
.PROGRAM mcp.main( )
; ABSTRACT:  This program creates and monitors a menu structure on the
;   MCP.
;
; INPUT PARAMS: None
;
; OUTPUT PARAMS: None
;
; GLOBAL VARS: mcp              MCP logical unit
           mcp.clr.scr          pendant control code, clear display & home
cursor
           mcp.cur.pos          pendant control code, set cursor position
           mcp.off.led          pendant control code, turn off an LED
           mcp.blink.char       pendant control code, start blink position
           mcp.noblink.char     pendant control code, disable blink position
           mcp.beep             pendant control code, beep the pendant
           mcp.tab              pendant control code, tab to next soft button
           mcp.on.led           pendant control code, turn on an LED

    AUTO button  ;Number of the soft button pressed
    AUTO quit    ;Boolean indicating menu structure should be exited

    mcp = 1
    quit = FALSE
    mcp.clr.scr = 12
    mcp.cur.pos = 18
    mcp.off.led = 28
    mcp.blink.char = 2
    mcp.noblink.char = 3
    mcp.beep = 7
    mcp.tab = 9
    mcp.on.led = 31

; Check to see if the MCP is free

    IF PENDANT(-3) <> 2 THEN
        GOTO 100
    END

; Attach to the MCP

    ATTACH (mcp)

; Verify ATTACH was successful

    IF IOSTAT(mcp) <> 1 THEN
        GOTO 100
    END
```

```
    DO ;Main processing loop

; Display the top-level menu

        CALL mcp.disp.main( )

; Get the operator selection (must be between 1 and 5)

        DO
            button = PENDANT(0)
        UNTIL (button < 6)

; Turn on the LED of the selected button

        WRITE (mcp) $CHR(mcp.on.led), $CHR(button), /S


; Respond to the menu item selected

        CASE button OF
          VALUE 1:; Verify program exit
            CALL mcp.main.quit(quit)

          VALUE 2:
            CALL mcp.option.2( )

          VALUE 3:
            CALL mcp.option.3( )

          VALUE 4:
            CALL mcp.option.4( )

          VALUE 5:
            CALL mcp.option.5( )

        END ;CASE button of

; Turn off LED

        WRITE (mcp) $CHR(mcp.off.led), $CHR(button), /S

    UNTIL quit

; Detach from the MCP

    DETACH (mcp)

100 IF NOT quit THEN;Exit on MCP busy
        TYPE /C34, /U17, "The MCP is busy or not connected."
        TYPE "Press the REC/DONE button to clear.", /C5
    END

.END
```

```
.PROGRAM mcp.disp.main( )

; ABSTRACT: This program is called to display a main menu above the five
;   soft keys on the MCP. The program assumes the MCP has been attached.
;
; INPUT PARAMS: None
;
; OUTPUT PARAMS: None
;
; GLOBAL VARS: mcp MCP logical unit
       mcp.clr.scr pendant control code, clear display & home cursor
       mcp.cur.pos pendant control code, set cursor position
       mcp.beep    pendant control code, beep the pendant
       mcp.tab     pendant control code, tab to next soft button


; Clear the display and write the top line

    WRITE (mcp) $CHR(mcp.clr.scr), $CHR(mcp.cur.pos), $CHR(16), "MAIN MENU", /S

; Write the menu options

    WRITE (mcp) $CHR(mcp.cur.pos), $CHR(41), /S
    WRITE (mcp) "Option5", $CHR(mcp.tab), "Option4", $CHR(mcp.tab), /S
    WRITE (mcp) "Option3", $CHR(mcp.tab), "Option2", $CHR(mcp.tab), "   QUIT", /S

; Beep the MCP

    WRITE (mcp) $CHR(mcp.beep), /S

.END



.PROGRAM mcp.main.quit(quit)

; ABSTRACT: This program responds to a "Quit" selection from the MCP
;   main menu.  It verifies the selection and passes the result.
;
; INPUT PARAMS: None
;
; OUTPUT PARAM: quitboolean indicating whether a "quit"
;                   has been verified
;
; GLOBAL VARS: mcp              MCP logical unit
;       mcp.clr.scr             pendant control code, clear display & home
cursor
;       mcp.off.led             pendant control code, turn off an LED
;       mcp.blink.char          pendant control code, start blink position
;       mcp.noblink.char        pendant control code, disable blink position
;       mcp.tab - pendant       control code, tab to next soft button
;
;

    quit = FALSE ;assume quit will not be verified
```

```
; Display sub-menu and start the "NO" option blinking

    WRITE (mcp) $CHR(mcp.clr.scr), "Quit. Are you sure?"
    WRITE (mcp) $CHR(mcp.tab), $CHR(mcp.tab), $CHR(mcp.tab), "  YES", /S
    WRITE (mcp) $CHR(mcp.tab), $CHR(mcp.blink.char), "  NO",
$CHR(mcp.noblink.char), /S
    button = PENDANT(0)

; Set quit to true if verified, else turn off the "NO" soft button LED

    IF button == 2 THEN
        quit = TRUE
    ELSE
        WRITE (mcp) $CHR(mcp.off.led), $CHR(1), /S
    END
.END
```

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This chapter describes the Adept Conveyor Tracking (moving-line) feature. The moving-line feature allows the programs to specify locations that are automatically modified to compensate for the instantaneous position of a conveyor belt. Motion locations that are defined relative to a belt can be taught and played back while the belt is stationary or moving at arbitrarily varying speeds. Conveyor tracking is available only for systems that have the optional V+ Extensions software.

For V+ to determine the instantaneous position and speed of a belt, the belt must be equipped with a device to measure its position and speed. As part of the moving-line hardware option, Adept provides an encoder and an interface for instrumenting two separate conveyor belts. Robot motions and locations can be specified relative to either belt.

There are no restrictions concerning the placement or orientation of a conveyor belt relative to the robot. In fact, belts that move uphill or downhill (or at an angle to the reference frame of the robot) can be treated as easily as those that move parallel to an axis of the robot reference frame. The only restriction regarding a belt is that its motion must follow a straight-line path in the region where the robot is to work.

The following sections contain installation and application instructions for using the moving-line feature. Before using this chapter, you should be familiar with V+ and the basic operation of the robot.

11.1 Installation

To set up a conveyor belt for use with a robot controlled by the V+ system.

1. Install all the hardware components and securely fasten them in place. The conveyor frame and robot base must be mounted rigidly so that no motion can occur between them.
2. Install the encoder on the conveyor.
3. Since any jitter of the encoder will be reflected as jitter in motions of the robot while tracking the belt, make sure the mechanical connection between the belt and the encoder operates smoothly. In particular, eliminate any backlash in gear-driven systems.
4. Wire the encoder to the robot controller. (See the controller user's guide for location of the encoder ports.)
5. Start up the robot system controller in the normal manner.
6. Calibrate the location of the conveyor belt relative to the robot by executing the Belt Calibration Program. That program is provided in the file BELT_CAL.V2 on the Adept Utility Disk supplied with your robot system.[1]

When these steps have been completed, the system is ready for use. However, each time the system is restarted, the belt calibration data must be reloaded (from the disk file created in the above steps). The next section describes loading belt calibration.

[1] See the *Instructions for Adept Utility Programs* for details.

11.2 Calibration

The position and orientation of the conveyor belt must be precisely known in order for the robot to track motion of the belt. The file BELT_CAL.V2 on the Adept Utility Disk contains a program to calibrate the relationship between the belt and the robot. The program saves the calibration data in a disk file for later use by application programs.

The DEFBELT and WINDOW program instructions must be executed before the associated belt is referenced in a V+ program. We suggest you include these instructions in an initialization section of your application program. Although these instructions need be executed only once, no harm is done if they are executed subsequently.

The file LOADBELT.V2 on the Adept Utility Disk contains a V+ subroutine that will load the belt calibration data from a disk file and execute the DEFBELT and WINDOW instructions. (See the next section.)

While the robot is moving relative to a belt (including motions to and from the belt), all motions must be of the straight-line type. Thus APPROS, DEPARTS, MOVES, and MOVEST can be used, but APPRO, DEPART, DRIVE, MOVE, and MOVET cannot. Motion relative to a belt is terminated by having the robot move to a location that is not defined relative to the belt variable, or when a belt-window violation occurs.

11.3 Basic Programming Concepts

This section describes the basic concepts of the Conveyor Belt Tracking feature. First, the data used to describe the relationship of the conveyor belt to the robot is presented. Then a description of how belt-relative motion instructions are specified is given. Finally, a description is presented of how belt-relative locations are taught.

The V+ operations associated with belt tracking are disabled when the BELT system switch is disabled. Thus, application programs that use those operations must be sure the BELT switch is enabled.

Belt Variables

The primary mechanism for specifying motions relative to a belt is a V+ data type called a belt variable. By defining a belt variable, the program specifies the relationship between a specific belt encoder and the location and speed of a reference frame that maintains a fixed position and orientation relative to the belt. Alternatively, a belt variable can be thought of as a transformation (with a time-varying component) that defines the location of a reference frame fixed to a moving conveyor. As a convenience, more than one belt variable can be associated with the same physical belt and belt encoder. In this way, several work stations can be easily referenced on the same belt.

Like other variable names in V+, the names of belt variables are assigned by the programmer. Each name must start with a letter and can contain only letters, numbers, periods, and underline characters. (Letters used in variable names can be entered in either lowercase or uppercase. V+ always displays variable names in lowercase.)

To differentiate belt variables from other data types, the name of a belt variable must be preceded by a percent sign (%). As with all other V+ data types, arrays of belt variables are permitted. Hence the following are all valid belt-variable names:

```
%pallet.on.belt    %base.plate    %belt[1]
```

The DEFBELT instruction must be used to define belt variables (see the "Moving-Line Programming" section of this chapter). Thus, the following are **not** valid operations:

```
SET %new_belt = %old_belt    or   HERE %belt[1]
```

Compared to other V+ data types, the belt variable is rather complex in that it contains several different types of information. Briefly, a belt variable contains the following information:

1. The nominal transformation for the belt. This defines the position and direction of travel of the belt and its approximate center.
2. The number of the encoder used for reading the instantaneous location of the belt (either 1 or 2).
3. The belt encoder scaling factor, which is used for converting encoder counts to millimeters of belt travel.
4. An encoder offset, which is used to adjust the origin of the belt frame of reference.
5. Window parameters, which define the working range of the robot along the belt.

These components of belt variables are described in detail in the following sections.

Unlike other V+ data types, belt variables cannot be stored in a disk file for later loading. However, the location and real-valued data used to define a belt variable can be stored and loaded in the normal ways. After the data is loaded from disk, DEFBELT and WINDOW instructions must be executed to define the belt variable. (The file LOADBELT.V2 on the Adept Utility Disk contains a subroutine that will read belt data from a disk file and execute the appropriate DEFBELT and WINDOW instructions.)

Nominal Belt Transformation

The position, orientation, and direction of motion of a belt are defined by a transformation called the nominal belt transformation. This transformation defines a reference frame aligned with the belt as follows: its X-Y plane coincides with the plane of the belt, its X axis is parallel to the direction of belt motion and its origin is located at a point (fixed in space) chosen by the user.

Since the direction of the X axis of the nominal belt transformation is taken to be the direction along which the belt moves, this component of the transformation must be determined with great care. Furthermore, while the point defined by this transformation (the origin of the frame) can be selected arbitrarily, it should normally be approximately at the middle of the robot's working range on the belt. This transformation will usually be defined using the FRAME location-valued function with recorded robot locations on the belt. (The easiest way to define nominal belt transformation is with the conveyor belt calibration program provided by Adept.)

The instantaneous location described by the belt variable will almost always be different from that specified by the nominal transformation. However, since the belt is constrained

to move in a straight line in the working area, the instantaneous orientation of a belt variable is constant and equal to that defined by the nominal belt transformation.

To determine the instantaneous location defined by a belt variable, the V+ system performs a computation that is equivalent to multiplying a unit vector in the X direction of the nominal transformation by a distance (which is a function of the belt encoder reading) and adding the result to the position vector of the nominal belt transformation. Symbolically, this can be represented as

```
instantaneous_XYZ =
nominal_XYZ + (belt_distance * X_direction_of_nominal_transform)
```

where

```
belt_distance =
(encoder_count - encoder_offset) * encoder_scaling_factor
```

The encoder variables contained in this final equation will be described in later sections.

The Belt Encoder

Two belt encoders are supported by the conveyor tracking feature. When specified as a component of a belt variable, these encoders are referred to as number "1" and number "2".

Each belt encoder generates pulses that indicate both the distance that the belt has moved and the direction of travel. The pulses are counted by the belt interface, and the count is stored as a signed 24-bit number. Therefore, the value of an encoder counter can range from $2^{23}-1$ (8,388,607) to -2^{23} (– 8,388,608). For example, if a single count of the encoder corresponds to 0.02 millimeters (0.00008 inch) of belt motion, then the full range of the counter would represent motion of the belt from approximately –167 meters (–550 feet) to +167 meters (+550 feet).

After a counter reaches its maximum positive or negative value, its value will "roll over" to the maximum negative or positive value, respectively. This means that if the encoder value is increasing and a rollover occurs, the sequence of encoder counter values will be: ... ; 8,388,606; 8,388,607; -8,388,608; -8,388,607; ... As long as the distance between the workspace of the robot and the nominal transformation of the belt is within the distance that can be represented by the maximum encoder value, V+ application programs normally do not have to take into account the fact that the counter will periodically roll over. The belt_distance equation described above is based upon a relative encoder value:

```
encoder_count – encoder_offset
```

and V+ automatically adjusts this calculation for any belt rollover that may occur.

Care must be exercised, however, if an application processes encoder values in any way. For example, a program may save encoder values associated with individual parts on the conveyor, and then later use the values to determine which parts should be processed by the robot. In such situations the application program may need to consider the possibility of rollover of the encoder value.

> **NOTE:** While the encoder counter value is stored as a 24-bit number, the rate of change of the belt encoder (the speed of the belt) is maintained only as a 16-bit number. The belt speed is used internally by V+ to predict

future positions on the belt. Therefore, the rate of change of the belt encoder should not exceed 32,768 counts per 16 milliseconds. The Adept application program for belt calibration includes a test for this condition and prints a warning if this restriction will be violated. This requirement will be a limitation only for very high-speed conveyors with very high-resolution encoders.

The Encoder Scaling Factor

For any given conveyor/encoder installation, the encoder scaling factor is a constant number that represents the amount the encoder counter changes during a change in belt position. The units of the scaling factor are "millimeters/count".

This factor can be determined either directly from the details of the mechanical coupling of the encoder to the belt or experimentally by reading the encoder as the belt is moved. The Adept belt calibration program supports either method of determining the encoder scaling factor.

If the encoder counter decreases as the belt moves in its normal direction of travel, the scaling factor will have a negative value.

The Encoder Offset

The last encoder value needed for proper operation of the moving-line system is the belt encoder offset. The belt encoder offset is used by V+ to establish the instantaneous location of the belt reference frame relative to its nominal location.

In particular, if the belt offset is set equal to the current belt encoder reading, the instantaneous belt transformation will be equal to the nominal transformation. The belt encoder offset can be used, in effect, to zero the encoder reading, or to set it to a particular value whenever necessary. Unlike the encoder scaling factor, which is constant for any given conveyor/encoder setup, the value of the belt encoder offset is variable and will usually be changed often.

Normally, the instantaneous location of the reference frame will be established using external input from a sensory device such as a photocell or the AdeptVision system. For example, the VFEATURE function provided by AdeptVision returns as one of its computed values the belt encoder offset that must be set in order to grasp an object identified by the vision system. The DEVICE real-valued function also returns latched or unlatched encoder values for use with SETBELT.

The encoder offset is set with the SETBELT program instruction, as described later.

The Belt Window

The belt window controls the region of the belt in which the robot is to work. A window is a segment of the belt bounded by two planes that are perpendicular to the direction of travel of the belt. (Note that a window has limits only in the direction along the belt.)

Within V+, a belt window is defined by two transformations with a WINDOW program instruction. The window boundaries are computed by V+ as planes that are perpendicular to the direction of travel of the belt and that pass through the positions defined by the transformations.

If the robot attempts to move to a belt-relative location that has not yet come within the window (is "upstream" of the window), the robot can be instructed either to pause until it can accomplish the motion or immediately generate a program error. If a destination moves out of the window (is "downstream" of the window), it is flagged as an error condition and the application program can specify what action is to be taken. (See the description of the BELT.MODE system parameter in *V+ Language Reference Guide*.)

If the normal error testing options are selected, whenever the V+ system is planning a robot motion to a belt-relative location and the destination is outside the belt window but upstream, the system automatically delays motion planning until the destination is within the window. However, if an application program attempts to perform a motion to a belt-relative destination that is out of the window at planning time (or is predicted to be out by the time the destination would be reached) and this destination is downstream, a window-violation condition exists. Also, if during the execution of a belt-relative motion or while the robot is tracking the belt, the destination moves outside the belt window for any reason, a window violation occurs. Depending upon the details of the application program, the program either prints an error message and halts execution or branches to a specified subroutine when a window violation occurs.

In order to provide flexibility with regard to the operation of the window-testing mechanism, several modifications to the normal algorithms can be selected by modifying the value of the BELT.MODE system parameter.

To assist in teaching the belt window, the Adept conveyor belt calibration program contains routines that lead the operator through definition of the required bounding transformations.

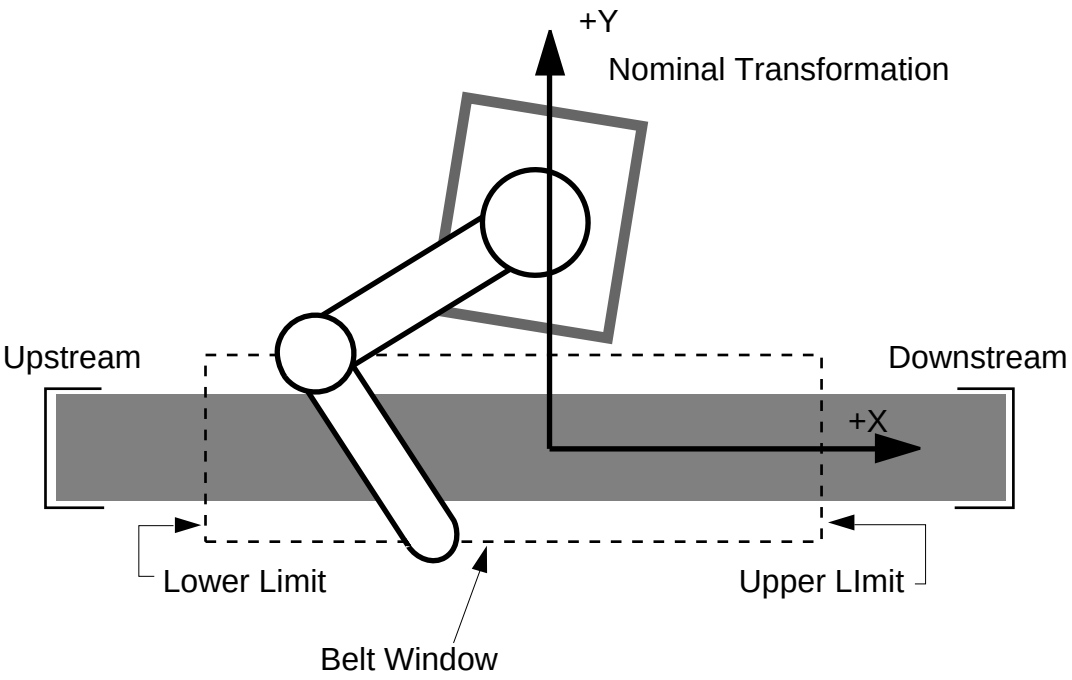

Figure 11-1. **Conveyor Terms**

Belt-Relative Motion Instructions

To define a robot motion relative to a conveyor belt, or to define a relative transformation with respect to the instantaneous location of a moving frame of reference, a belt variable can be used in place of a "regular" transformation in a compound transformation. For example, the instruction

```
MOVES %belt:loc_1
```

directs the robot to perform a straight-line motion to location "loc_1", which is specified relative to the location defined by the belt variable "%belt". If a belt variable is specified, it must be the first (that is, leftmost) element in a compound transformation. Only one belt variable can appear in any compound transformation.

Motions relative to a belt can be only of the straight-line type. Attempting a joint-interpolated motion relative to a belt causes an error and halts execution of the application program. Except for these restrictions, motion statements that are defined relative to a belt are treated just like any other motion statement. In particular, continuous-path motions relative to belts are permitted.

Once the robot has been moved to a destination that is defined relative to a belt, the robot tool will continue to track the belt until it is directed to a location that is not relative to the belt. For example, the following series of instructions would move the tool to a location relative to a belt, open the hand, track the belt for two seconds, close the hand, and finally move "off" the belt to a fixed location.

```
MOVES %belt[1]:location3
OPENI
DELAY 2.00
CLOSEI
MOVES fixed.location
```

If this example did not have the second MOVES statement, the robot would continue to track the belt until a belt window violation occurred.

As with motions defined relative to a belt, motions that move the tool off a belt (that is, to a fixed location) must be of the straight-line type.

Motion Termination

When moving the robot relative to a belt, special attention must be paid to the conditions used to determine when a motion is completed. At the conclusion of a continuous-path motion V^+ normally waits until all the joints of the manipulator have achieved their final destinations to within a tight error tolerance before proceeding to the next instruction. In the case of motions relative to a belt, the destination is constantly changing and, depending upon the magnitude and variability of the belt speed, the robot may not always be able to achieve final positions with the default error tolerance.

Therefore, if a motion does not successfully complete (that is, it is aborted due to a "Time-out nulling" error), or if it takes an excessive amount of time to complete, the error tolerance for the motion should be increased by preceding the motion instruction with a

COARSE instruction. In extreme situations it may even be necessary to entirely disable checking of the final error tolerance. This can be done by specifying NONULL before the start of the motion.

Defining Belt-Relative Locations

In order to define locations relative to a belt, belt-relative compound transformations can be used as parameters to all the standard V+ teaching aids. For example, all the following commands define a location "loc_1" relative to the current belt location:[1]

```
HERE %belt:loc_1

POINT %belt:loc_1

TEACH %belt:loc_1
```

In each of these cases, the instantaneous location corresponding to "%belt" would be determined (based upon the reading of the belt encoder associated with %belt) and "loc_1" would be set equal to the difference between the current tool location and the instantaneous location defined by %belt.

While a belt variable can be used as the first (leftmost) element of a compound transformation to define a transformation value, a belt variable cannot appear by itself. For example, LISTL will not display a belt variable directly. To view the value of a belt variable, enter the command:

```
LISTL %belt_variable:NULL
```

11.4 Moving-Line Programming

This section describes how to access the moving-line capabilities within V+. A functional overview is presented that summarizes the extensions to V+ for Conveyor Tracking. All the V+ moving-line keywords are described in detail in *V+ Language Reference Guide*.

The moving-line extensions to V+ include:

- Instructions and functions (there are no monitor commands)
- System switch
- System parameters

Instructions and Functions

This section summarizes the V+ instructions and functions dedicated to moving-line processing. The belt-related functions return real values.

---

[1] Before defining a location relative to a belt, you must make sure the belt encoder offset is set properly. That usually involves issuing a monitor command in the form:

```
DO SETBELT %belt = BELT(%belt)
```

Belt Variable Definition

The following keywords are used to define the parameters of belt variables. Some parameters are typically set once, based upon information derived from the belt calibration procedure. Other parameters are changed dynamically as the application program is executing.

DEFBELT — Program instruction that creates a belt variable and defines its static characteristics: nominal transformation, encoder number, and encoder scaling factor.

SETBELT — Program instruction to set the encoder offset of a belt variable. This defines the instantaneous belt location relative to that of the nominal belt transformation.

WINDOW — Program instruction for establishing the belt window boundaries and specifying a window-violation error subroutine.

Encoder Position and Velocity Information

The following function is used to read information concerning the encoder associated with a belt variable.

BELT — Real-valued function that returns the instantaneous encoder counter value or the rate of change of the encoder counter value.

Window Testing

The following function allows an application program to incorporate its own specialized working-region strategy, independent of the strategy provided as an integral part of the V+ conveyor tracking system.

WINDOW — Real-valued function that indicates where a belt-relative location is (or will be at some future time) relative to a belt window.

Status Information

The following function indicates the current operating status of the moving-line software.

BSTATUS — Real-valued function that returns bit flags indicating the status of the moving-line software.

System Switch

The switch BELT, enables / disables the operation of the moving-line software. (See the description of ENABLE, DISABLE, and SWITCH for details on setting and displaying the value of BELT.)

BELT — This switch must be enabled before any conveyor tracking processing begins.

System Parameters

The following parameter selects alternative modes of operation of the belt window testing routines. See the description of PARAMETER for details on setting and displaying the parameter values.

BELT.MODE	Bit flags for selecting special belt window testing modes of operation.

11.5 Sample Programs

The following program is an example of a robot task working from a conveyor belt. The task consists of the following steps:

1. Wait for a signal that a part is present.
2. Pick up the part.
3. Place the part at a new location on the belt.
4. Return to a rest location to wait for the next part.

CAUTION: These programs are meant only to illustrate programming techniques useful in typical applications. Moving-line programs are hardware dependent because of the belt parameters, so care must be exercised if you attempt to use these programs.

```
; *** PROGRAM TO RELOCATE PART ON CONVEYOR ***
; Setup belt parameters

ENABLE BELT
PARAMETER BELT.MODE = 0
belt.scale = 0.030670       ;Encoder scale factor


; Define belt twice, for two stations

DEFBELT %b1 = belt, 1, 32, belt.scale
WINDOW %b1 = window.1, window.2, window.error
DEFBELT %b2 = belt, 2, 32, belt.scale
WINDOW %b2 = window.1, window.2, window.error

WHILE TRUE DO               ;Loop indefinitely
    WAIT part.ready         ;Wait for signal that part present
    bx = BELT(%b1)          ;Read present belt position
    SETBELT %b1 = bx        ;Set encoder offset for pick-up...
    SETBELT %b2 = bx        ;... and drop-off stations
    APPROS %b1:p1, 50.00    ;Move to the part and pick it up
    MOVES %b1:p1
    CLOSEI
    DEPARTS 50.00
    APPROS %b2:p2, 50.00    ;Carry part to drop-off location
    MOVES %b2:p2
    OPENI DEPARTS 50.00
```

```
    MOVES wait.location     ;Return to rest location
END                         ;Wait for the next part

; *** End of program ***
```

The WINDOW instruction in the above program indicates that whenever a window violation occurs, a subroutine named “window.error” is to be executed. The following is an example of what such a routine might contain.

```
; *** WINDOW VIOLATION ROUTINE ***

TYPE /B, /C1, "** WINDOW ERROR OCCURRED **", /C1

; Find out which end of window was violated

IF DISTANCE(HERE, window.1) < DISTANCE(HERE, window.2) THEN

; Error occurred at window.2

    TYPE "Part moved downstream out of reach"
    ;...(Respond to downstream window error) .
ELSE                            ; Error occurred at window.1

    TYPE "Part moved upstream out of reach"
    ;...(Respond to upstream window error) .
END

MOVES wait.location         ;Move robot to rest location

; Use digital output signals to sound alarm and stop belt

SIGNAL alarm, stop.belt

HALT                            ;Halt program execution
```

Example V+ Programs A

This appendix contains a sampling of V+ programs. The first program is presented twice: once in its entirety exactly as it would be displayed by V+, and a second time with a line-by-line explanation.

The program keywords are detailed in *V+ Language Reference Guide*.

> **NOTE:** The programs in this manual are not necessarily complete. In most cases further refinements could be added to improve the programs. For example, the programs could be made more tolerant of unusual events such as error conditions.

A.1 Pick and Place

This program demonstrates a simple pick-and-place application. The robot picks up parts at one location and places them at another.

Features Introduced

- Program initialization
- Variable assignment
- System parameter modification
- FOR loop
- Motion instructions
- Hand control
- Terminal output

Program Listing

```
.PROGRAM move.parts()

 ; ABSTRACT: Pick up parts at location “pick” and put them down at “place”

          parts = 100                     ;Number of parts to be processed

          height1 = 25.4                  ;Approach/depart height at "pick"

          height2 = 50.8                  ;Approach/depart height at "place"

          PARAMETER HAND.TIME = 0.16      ;Setup for slow hand
```

```
    OPEN                          ;Make sure the hand is open
    RIGHTY                        ;Make sure configuration is correct
    MOVE start                    ;Move to safe starting location

    FOR i = 1 TO parts   ;Process the parts

        APPRO pick, height1       ;Go toward the pick-up
        MOVES pick                ;Move to the part
        CLOSEI                    ;Close the hand
        DEPARTS height1           ;Back away

        APPRO place, height2      ;Go toward the put-down
        MOVES place               ;Move to the destination
        OPENI                     ;Release the part
        DEPARTS height2           ;Back away

    END                           ;Loop for next part

    TYPE "All done. ", /I0, parts, " parts processed"

    RETURN                        ;End of the program
.END
```

Detailed Description

This program has five sections: formal introduction, initialization of variables, initialization of the robot location, performance of the desired motion sequence, and notice to the operator of completion of the task. Each of these sections is described in detail below.

The first line of every program must have the form of the line below. It is a good practice to follow that line with a brief description of the purpose of the program. If there are any special requirements for use of the program, they should be included as well.

`.PROGRAM move.parts()`

This line identifies the program to the V+ system. In this case we see that the name of the program is “move.parts”.

`; ABSTRACT: Pick up parts at location "pick" and put them down at "place"`

This is a very brief description of the operation performed by the program. (Most programs will require a more extensive summary.)

Use variables to represent constants for two reasons: Using a variable name throughout a program makes the program easier to understand, and only one program line needs to be modified if the value of the constant must be changed.

`parts = 100`

Tell the program how many parts to process during a production run. In this case, 100 parts will be processed.

`height1 = 25.4`

“height1” controls the height of the robot path when approaching and departing from the location where the parts are to be picked up. Here it is set to 25.4 millimeters (that is, 1 inch).

`height2 = 50.8`

Similar to “height1”, “height2” sets the height of the robot path when approaching and departing from the put-down location. It is set to 50.8 millimeters (2 inches).

PARAMETER HAND.TIME 0.16

Set the system parameter HAND.TIME so sufficient time will be allowed for actuation of the robot hand.

This setting will cause OPENI and CLOSEI instructions to delay program execution for 160 milliseconds while the hand is actuated.

Other important initializing functions are to make sure the robot has the desired hand opening, is at a “safe” starting location, and that SCARA robots have the desired configuration.

`RIGHTY`

Make sure the robot has a right-handed configuration (with the elbow of the robot to the right side of the workspace). This is important if there are obstructions in the workspace that must be avoided.

This instruction will cause the robot to assume the requested configuration during its next motion.

`OPEN`

Make sure the hand is initially open. This instruction will have its effect during the next robot motion, rather than delaying program execution as would be done by the OPENI instruction.

`MOVE start`

Move to a safe starting location. Due to the preceding two instructions, the robot will assume a right-handed configuration, with the hand open.

The location “start” must be defined before the program is executed. That can be done, for example, with the HERE command. The location must be chosen such that the robot can move from it to the pick-up location for the parts without hitting anything.

After initialization, the following program section performs the application tasks.

`FOR i = 1 TO parts`

Start a program loop. The following instructions (down to the “END”) will be executed “parts” times. After the last time the loop is executed, program execution will continue with the TYPE instruction following the END below.

`APPRO pick, height1`

Move the robot to a location that is “height1” millimeters above the location “pick”.

The APPROS instruction is not used here because its straight-line motion would be slower than the motion commanded by APPRO.

```
MOVES pick
```

Move the robot to the pick-up location “pick”, which must have been defined previously.

The straight-line motion commanded by MOVES assures that the hand does not hit the part during the motion. A MOVE instruction could be used here if there is sufficient clearance between the hand and the part to allow for a non-straight-line path.

```
CLOSEI
```

Close the hand. To assure that the part is grasped before the robot moves away, the “I” form of the CLOSE instruction is used— program execution will be suspended while the hand is closing.

```
DEPARTS height1
```

Now that the robot is grasping the part, we can back away from the part holder. This instruction will move the hand back “height1” millimeters, following a straight-line path to make sure the part does not hit its holder.

```
APPRO place, height2
MOVES place
OPENI
DEPARTS height2
```

Similar to the above motion sequence, these instructions cause the part to be moved to the put-down location and released.

```
END
```

This marks the end of the FOR loop. When this instruction is executed, control is transferred back to the FOR instruction for the next cycle through the loop (unless the loop count specified by “parts” is exceeded).

The final section of the program simply displays a message on the system terminal, and terminates execution.

```
TYPE "All done. ", /I3, parts, " pieces processed."
```

The above instruction will output the message:

```
All done. 100 pieces processed.
```

(The “/I0” format specification in the instruction causes the value of “parts” to be output as an integer value without a decimal point.)

```
RETURN
```

Although not absolutely necessary for proper execution of the program, it is good programming practice to include a RETURN (or STOP) instruction at the end of every program.

```
.END
```

This line is automatically included by the V+ editor to mark the program’s end.

A.2 Menu Program

This program displays a "menu" of operations from which an operator can choose.

Features Introduced

- Subroutines
- Local variables
- Terminal interaction with operator
- String variables
- WHILE and CASE structures

Program Listing

```
.PROGRAM sub.menu()

     ; ABSTRACT: This program provides the operator with a menu of
     ;   operation selections on the system terminal. After accepting
     ;   input from the keyboard, the program executes the desired
     ;   operation. In this case, the menu items include execution of
     ;   the pick and place program, teaching locations for the pick
     ;   and place program, and returning to a main menu.
     ;
     ; SIDE EFFECTS: The pick and place program may be executed and
     ;   locations may be defined.

               AUTO choice, quit, $answer

               quit = FALSE

               DO

                    TYPE /C2, "PICK AND PLACE OPERATIONAL MENU"
                    TYPE /C1, " 1 => Initiate pick and place"
                    TYPE /C1, " 2 => Teach locations"
                    TYPE /C1, " 3 => Return to previous menu", /C1

                    PROMPT "Enter selection and press RETURN: ", $answer

                    choice = VAL($answer)          ;Convert string to number

                    CASE choice OF                 ;Process menu request...
                      VALUE 1:                     ;...selection 1
                         TYPE /C2, "Initiating Operation..."
                         CALL move.parts()
                      VALUE 2:                     ;...selection 2
                         CALL teach()
                      VALUE 3:                     ;...selection 3
                         quit = TRUE
                      ANY                          ;...any other selection
                         TYPE /B, /C1, "** Invalid input **"
                    END                            ;End of CASE structure
               UNTIL quit                          ;End of DO structure

.END
```

A.3 Teaching Locations With the MCP

This program demonstrates how an operator can teach locations with the manual control pendant, thus allowing the controller to operate without a system terminal. The two-line liquid crystal display (LCD) of the pendant is used to prompt the operator for the locations to be taught. The operator can then manually position the robot at a desired location and press a key on the pendant. The program automatically records the location for later use (in this case, for the pick-and-place program).

Features Introduced

- Subroutine parameters
- Attachments and detachments
- Manual control pendant interaction
- WAIT instruction
- Location definition within a program

Program Listing

```
.PROGRAM teach(pick, place, start)

 ; ABSTRACT: This program is used for teaching the locations
 ;         "pick", "place", and "start" for the "move.parts" program.
 ;
 ; INPUT PARAM:  None
 ;
 ; OUTPUT PARAM:  pick, place, and start
 ;
 ; SIDE EFFECTS: Robot is detached while this routine is active

           AUTO $clear.display

           $clear.display = $CHR(12)+$CHR(7)

           ATTACH (1)                ;Connect to the pendant
           DETACH (0)                ;Release control of the robot

 ; Output prompt to the display on the manual control pendant

           WRITE (1) $clear.display, "Move robot to 'START' & press RECORD"
           WRITE (1) /X17, "RECORD", $CHR(5), /S
           WRITE (1) $CHR(30), $CHR(3), /S ;Blink LED on control pendant

           WAIT PENDANT(3)           ;Wait for key to be pressed

           HERE start                ;Record the location "start"

 ; Prompt for second location

           WRITE (1) $clear.display, "Move robot to 'PICK' & press RECORD"
           WRITE (1) /X17, "RECORD", $CHR(5), /S

           WAIT PENDANT(3)           ;Wait for key to be pressed
```

```
          HERE pick                 ;Record the location "pick"

; Prompt for third location

          WRITE (1) $clear.display, "Move robot to 'PLACE' & press RECORD"
          WRITE (1) /X17, "RECORD", $CHR(5), /S

          WAIT PENDANT(3)           ;Wait for key to be pressed

          HERE place                ;Record the location "place"

          ATTACH (0)                ;Reconnect to the robot
          DETACH (1)                ;Release the pendant

          RETURN                    ;Return to calling program
.END
```

External Encoder Device B

The external-encoder inputs on the system controller are normally used for conveyor belt tracking with a robot. However, these inputs also can be used for other sensing applications. In such applications, the DEVICE real-valued function and SETDEVICE program instruction allow the external encoders to be accessed in a more flexible manner than the belt-oriented instructions and functions.

This appendix describes the use of the DEVICE real-valued function and the SETDEVICE program instruction to access the external encoder device.

In general, SETDEVICE allows a scale factor, offset, and limits to be specified for a specified external encoder unit. The DEVICE real-valued function returns error status, position, or velocity information for the specified encoder.

Accessing the external encoders via DEVICE and SETDEVICE is independent of any belt-tracking commands or instructions. Setting belt parameters with SETBELT and setting encoder parameters with SETDEVICE have no affect on each other. The only exceptions are the SETDEVICE "initialize" command and "reset" command, which reset all errors for the specified external encoder—including any belt-related errors.

> **NOTE:** See *V+ Language Reference Guide* for complete information on the DEVICE real-valued function and the SETDEVICE program instruction.

B.1 Parameters

The external encoder **device type** is 0. This means that the "type" parameter in all DEVICE or SETDEVICE instructions that reference the external encoders must have a value of 0.

The standard Adept controller allows two external encoder units. These **units** are numbered 0 and 1. All DEVICE functions and SETDEVICE instructions that reference the external encoders must specify one of these unit numbers for the "unit" parameter.

B.2 Device Setup

The SETDEVICE program instruction allows the external encoders to be initialized, and various parameters to be set up. The action taken by the SETDEVICE instruction depends upon the value of the “command” parameter.

The syntax of the SETDEVICE instruction is

```
SETDEVICE (0, unit, error, command) p1, p2
```

The valid commands are described below:

Command	Description
0	Initialize Device This command sets all scale factors, offsets, and limits to their default values, as follows: offset = 0; scale factor = 1; no limit checking. This command also resets any errors for the specified device. This command should be issued before any other commands for a particular unit, and before using the DEVICE real-valued function for the unit.
1	Reset Device This command clears any errors associated with this encoder unit. It does not affect the scale factor, offset, or limits.
8	Set Scale Factor This command sets the position and velocity scale factor for this encoder unit to the value of parameter “p1”. The units are millimeters per encoder count. The scale factor must be set before setting the offset or limits. If the scale factor is changed, the offset and limit values will need to be updated.
9	Set Position Offset This command sets the position offset for this encoder unit to the value of parameter “p1”. The units are millimeters. The scale factor must be set before setting the offset.
10	Set Position Limits This command sets the position limits for the encoder unit to the values of optional parameters “p1” and “p2”, which are the lower and upper limits, respectively. If a parameter is omitted, no checking is performed for that limit. The units are millimeters. The scale factor must be set **before** setting the limits.

B.3 Reading Device Data

The DEVICE real-valued function returns information about the encoder error status, position, and velocity. The scale factor, offset, and limits defined by the SETDEVICE instruction affect the velocity and position values returned.

The syntax for this function is

```
DEVICE(0, unit, error, select)
```

The value returned depends upon the value of the "select" parameter, as described below:

select	Description
0	Read Hardware Status The error status of the encoder unit is returned as a 24-bit value. The valid error bits for this device are listed below. The "corresponding error" listed is the one V+ would report if the error occurred while tracking a belt encoder. Bit # Bit Mask Corresponding Error Message and Code 19 ^H040000 *Lost encoder sync* (–1012) 20 ^H080000 *Encoder quadrature error* (–1013) 21 ^H100000 *No zero index* (–1011) Only bit #20, for encoder quadrature error, is detected by the "error" parameter of the DEVICE function to generate an error.
1	Read Position The current position of the encoder (in millimeters) is returned, subject to the scale factor, offset, and limits defined by the SETDEVICE instruction. The value returned is computed by: position = scale∗(encoder-offset) position = MAX(position, lower_limit) position = MIN(position, upper_limit)
2	Read Velocity The current value of the encoder velocity (in millimeters per second) is returned; subject to the scale factor defined by the SETDEVICE instruction. The value returned is computed by: velocity = scale*encoder_velocity
3	Read Predicted Position The predicted position of the encoder (in millimeters) is returned. The position is predicted 32 milliseconds in the future, based upon the current position and velocity. The value is scaled the same as the current position described above.
4	Read Latched Position The position or the encoder (in millimeters) when the last external trigger occurred is returned. The LATCHED real-valued function may be used to determined when an external trigger has occurred and a valid position has been recorded.

Character Sets C

Tables C-1 and C-2 list the standard Adept character set. Values 0 to 127 (decimal) are the standard ASCII character set. Characters 1 to 31 are the common set of special and line-drawing characters. Characters 0 and 127 to 141 are Adept additions to the standard sets. Characters 32 to 255 (excluding 127 through 141) are the ISO standard 8859-1 character set. Characters 145 to 159 are overstrike characters (see the OVERSTRIKE attribute to the /TERMINAL argument for the FSET instruction in the *V+ Language Reference Guide*). Values 1 to 31 are also given special meaning in the extended Adept character set when they are output to a graphics window with the GTYPE instruction.

> **NOTE:** The full character set is defined for font #1 only. Fonts #2 (medium font), #3 (large font), and #4 (small font) have defined characters for ASCII values 0 and 32 - 127. Fonts #5 and #6 have standard English characters for ASCII values 0 and 32 - 135 while ASCII 136 - 235 are Katakana and Hiragana characters. Font #5 is standard size and font #6 contains large characters. The last column in Table C-2 shows the Katakana and Hiragana characters. The Katakana characters are at ASCII 161 -223. The Hiragana characters are at ASCII 136 - 159 and 224 - 255.

Characters with values 0 to 31 and 127 (decimal) have the control meanings listed in Table C-1 when output to a serial line, an ASCII terminal, or the monitor window (with TYPE, PROMPT, or WRITE instructions). In files exported to other text editors or transmitted across serial lines, characters 0 to 31 will generally be interpreted as having the specified control meaning. The symbols shown for characters 0 to 31 and 127 in Table C-2 can be displayed only with the GTYPE instruction.

Characters in the extended Adept character set can be output using the $CHR function. For example:

```
TYPE $CHR(229)
```

will output the character å to the monitor window. The instruction:

```
GTYPE (glun) 50, 50, $CHR(229)
```

will output the same character to the window open on logical unit “glun”.

Table C-1. **ASCII Control Values**

Character	Decimal Value	Hex. Value	Meaning of Control Character
NUL	000	00	Null
SOH	001	01	Start of heading
STX	002	02	Start of text
ETX	003	03	End of text
EOT	004	04	End of transmission
ENQ	005	05	Enquiry
ACK	006	06	Acknowledgment
BEL	007	07	Bell
BS	008	08	Backspace
HT	009	09	Horizontal tab
LF	010	0A	Line feed
VT	011	0B	Vertical tab
FF	012	0C	Form feed
CR	013	0D	Carriage return
SO	014	0E	Shift out
SI	015	0F	Shift in
DLE	016	10	Data link escape
DC1	017	11	Direct control 1
DC2	018	12	Direct control 2
DC3	019	13	Direct control 3
DC4	020	14	Direct control 4
NAK	021	15	Negative acknowledge
SYN	022	16	Synchronous idle
ETB	023	17	End of transmission block
CAN	024	18	Cancel
EM	025	19	End of medium
SUB	026	1A	Substitute

Table C-1. **ASCII Control Values** (Continued)

Character	Decimal Value	Hex. Value	Meaning of Control Character
ESC	027	1B	Escape
FS	028	1C	File separator
GS	029	1D	Group separator
RS	030	1E	Record separator
US	031	1F	Unit separator
DEL	127	7F	Delete

Table C-2. **Adept Character Set**

Dec. Value	Hex. Value	Description	Font 1	Fonts 2, 3, 4, 5 & 6
000	00	cell outline	□	□
001	01	diamond	◆	
002	02	checkerboard	▒	
003	03	“HT” (Horizontal Tab)	$^{H}_{T}$	
004	04	“FF” (Form Feed)	$^{F}_{F}$	
005	05	“CR” (Carriage Return)	$^{C}_{R}$	
006	06	“LF” (Line Feed)	$^{L}_{F}$	
007	07	degree symbol	°	
008	08	plus/minus	±	
009	09	“NL” (New line)	$^{N}_{L}$	
010	0A	“VT” (Vertical Tab)	$^{V}_{T}$	
011	0B	lower right corner	┘	
012	0C	upper right corner	┐	
013	0D	upper left corner	┌	
014	0E	lower left corner	└	
015	0F	intersection	┼	
016	10	scan line 3	⁻	

Table C-2. **Adept Character Set** (Continued)

Dec. Value	Hex. Value	Description	Font 1	Fonts 2, 3, 4, 5 & 6
017	11	scan line 6	⎺	
018	12	scan line 9	⎻	
019	13	scan line 12	–	
020	14	scan line 15	_	
021	15	left T-bar	├	
022	16	right T-bar	┤	
023	17	bottom T-bar	┬	
024	18	top T-bar	┴	
025	19	vertical bar	│	
026	1A	less than or equal to	ð	
027	1B	greater than or equal to	Š	
028	1C	pi (lowercase)	¼	
029	1D	not equal to	¦	
030	1E	sterling	£	
031	1F	centered dot	·	
032	20	space		
033	21	exclaim	!	!
034	22	double quote	"	"
035	23	pound	#	#
036	24	dollar sign	$	$
037	25	percent	%	%
038	26	ampersand	&	&
039	27	single quote	'	'
040	28	open parens	(	(
041	29	close parens	)	)
042	2A	asterisk	*	*
043	2B	plus	+	+
044	2C	comma	,	,
045	2D	hyphen	-	-

Table C-2. **Adept Character Set** (Continued)

Dec. Value	Hex. Value	Description	Font 1	Fonts 2, 3, 4, 5 & 6
046	2E	period	.	.
047	2F	slash	/	/
048	30	zero	0	0
049	31	one	1	1
050	32	two	2	2
051	33	three	3	3
052	34	four	4	4
053	35	five	5	5
054	36	six	6	6
055	37	seven	7	7
056	38	eight	8	8
057	39	nine	9	9
058	3A	colon	:	:
059	3B	semi-colon	;	;
060	3C	less-than	<	<
061	3D	equal to	=	=
062	3E	greater than	>	>
063	3F	question	?	?
064	40	at	@	@
065	41	A	A	A
066	42	B	B	B
067	43	C	C	C
068	44	D	D	D
069	45	E	E	E
070	46	F	F	F
071	47	G	G	G
072	48	H	H	H
073	49	I	I	I
074	4A	J	J	J
075	4B	K	K	K
076	4C	L	L	L

Table C-2. **Adept Character Set** (Continued)

Dec. Value	Hex. Value	Description	Font 1	Fonts 2, 3, 4, 5 & 6
077	4D	M	M	M
078	4E	N	N	N
079	4F	O	O	O
080	50	P	P	P
081	51	Q	Q	Q
082	52	R	R	R
083	53	S	S	S
084	54	T	T	T
085	55	U	U	U
086	56	V	V	V
087	57	W	W	W
088	58	X	X	X
089	59	Y	Y	Y
090	5A	Z	Z	Z
091	5B	left bracket	[	[
092	5C	back slash	\	\
093	5D	right bracket	]	]
094	5E	circumflex (carat)	^	^
095	5F	underscore	_	_
096	60	grave accent	`	`
097	61	a	a	a
098	62	b	b	b
099	63	c	c	c
100	64	d	d	d
101	65	e	e	e
102	66	f	f	f
103	67	g	g	g
104	68	h	h	h
105	69	i	i	i
106	6A	j	j	j
107	6B	k	k	k

Table C-2. **Adept Character Set** (Continued)

Dec. Value	Hex. Value	Description	Font 1	Fonts 2, 3, 4, 5 & 6
108	6C	l	l	l
109	6D	m	m	m
110	6E	n	n	n
111	6F	o	o	o
112	70	p	p	p
113	71	q	q	q
114	72	r	r	r
115	73	s	s	s
116	74	t	t	t
117	75	u	u	u
118	76	v	v	v
119	77	w	w	w
120	78	x	x	x
121	79	y	y	y
122	7A	z	z	z
123	7B	right brace	{	{
124	7C	bar	|	|
125	7D	left brace	}	}
126	7E	tilde	~	~
127	7F	solid	▮	▮

Table C-2. **Adept Character Set** (Continued)

Dec. Value	Hex. Value	Description (roman chars.)	Font 1	Fonts 5 & 6
128	80	copyright	©	©
129	81	registered trademark	®	®
130	82	trademark	TM	TM
131	83	bullet	•	•
132	84	superscript “+”	+	+
133	85	double quote (modified)	"	"

Table C-2. **Adept Character Set** (Continued)

Dec. Value	Hex. Value	Description (roman chars.)	Font 1	Fonts 5 & 6
134	86	checkmark	✔	✔
135	87	right-pointing triangle	▶	▶
136	88	approximately equal symbol	Ý	o
137	89	OE ligature	Œ	a
138	8A	oe ligature	œ	i
139	8B	beta	β	u
140	8C	Sigma	∑	e
141	8D	Omega	Ω	o
142	8E	blank		ya
143	8F	blank		yu
144	90	dot-less i	ı	yo
145	91	grave accent	`	Dbl next consonant
146	92	acute accent	´	-
147	93	circumflex	^	A
148	94	tilde	~	I
149	95	macron	¯	U
150	96	breve	•	E
151	97	dot accent	•	O
152	98	dieresis	¨	KA
153	99	blank		KI
154	9A	ring	°	KU
155	9B	cedilla	¸	KE
156	9C	blank		KO
157	9D	hungarumlaut	″	SA
158	9E	ogonek	•	SHI
159	9F	caron	ˇ	SU

Table C-2. **Adept Character Set** (Continued)

Dec. Value	Hex. Value	Description (roman chars.)	Font 1	Fonts 5 & 6
160	A0	blank		Yen symbol
161	A1	inverted exclamation point	¡	Closed circle
162	A2	cent	¢	Start quote
163	A3	sterling	£	End quote
164	A4	currency	¤	Comma
165	A5	yen	¥	End sentence
166	A6	broken bar	|	o
167	A7	section	§	a
168	A8	dieresis	¨	i
169	A9	copyright	©	u
170	AA	feminine ordinal	ª	e
171	AB	left guillemot	«	o
172	AC	logical not	¬	ya
173	AD	en dash	–	yu
174	AE	registered	®	yo
175	AF	macron	¯	Dbl next consonant
176	B0	degree	°	-
177	B1	plus/minus	±	A
178	B2	superscript 2	²	I
179	B3	superscript 3	³	U
180	B4	acute accent	´	E
181	B5	mu	µ	O
182	B6	paragraph	¶	KA
183	B7	centered dot	·	KI
184	B8	cedilla	¸	KU
185	B9	superscript 1	¹	KE

Table C-2. **Adept Character Set** (Continued)

Dec. Value	Hex. Value	Description (roman chars.)	Font 1	Fonts 5 & 6
186	BA	masculine ordinal	º	KO
187	BB	right guillemot	»	SA
188	BC	1/4	1/4	SHI
189	BD	1/2	1/2	SU
190	BE	3/4	3/4	SE
191	BF	inverted question mark	¿	SO
192	C0	A grave	À	TA
193	C1	A acute	Á	CHI
194	C2	A circumflex	Â	TSU
195	C3	A tilde	Ã	TE
196	C4	A dieresis	Ä	TO
197	C5	A ring	Å	NA
198	C6	AE ligature	Æ	NI
199	C7	C cedilla	Ç	NU
200	C8	E grave	È	NE
201	C9	E acute	É	NO
202	CA	E circumflex	Ê	HA
203	CB	E dieresis	Ë	HI
204	CC	I grave	Ì	FU
205	CD	I acute	Í	HE
206	CE	I circumflex	Î	HO
207	CF	I dieresis	Ï	MA
208	D0	Eth	Đ	MI
209	D1	N tilde	Ñ	MU
210	D2	O grave	Ò	ME
211	D3	O acute	Ó	MO

Table C-2. **Adept Character Set** (Continued)

Dec. Value	Hex. Value	Description (roman chars.)	Font 1	Fonts 5 & 6
212	D4	O circumflex	Ô	YA
213	D5	O tilde	Õ	YU
214	D6	O dieresis	Ö	YO
215	D7	multiply	×	RA
216	D8	O slash	Ø	RI
217	D9	U grave	Ù	RU
218	DA	U acute	Ú	RE
219	DB	U circumflex	Û	RO
220	DC	U dieresis	Ü	WA
221	DD	Y acute	Ý	N
222	DE	Thorn	Þ	Voiced consonant
223	DF	German double s	ß	Voiced consonant-P
224	E0	a grave	à	SE
225	E1	a acute	á	SO
226	E2	a circumflex	â	TA
227	E3	a tilde	ã	CHI
228	E4	a dieresis	ä	TSU
229	E5	a ring	å	TE
230	E6	ae ligature	æ	TO
231	E7	c cedilla	ç	NA
232	E8	e grave	è	NI
233	E9	e acute	é	NU
234	EA	e circumflex	ê	NE
235	EB	e dieresis	ë	NO
236	EC	i grave	ì	HA
237	ED	i acute	í	HI

Table C-2. **Adept Character Set** (Continued)

Dec. Value	Hex. Value	Description (roman chars.)	Font 1	Fonts 5 & 6
238	EE	i circumflex	î	FU
239	EF	i dieresis	ï	HE
240	F0	eth	ƒ	HO
241	F1	n tilde	ñ	MA
242	F2	o grave	ò	MI
243	F3	o acute	ó	MU
244	F4	o circumflex	ô	ME
245	F5	o tilde	õ	MO
246	F6	o dieresis	ö	YA
247	F7	divide	÷	YU
248	F8	o slash	ø	YO
249	F9	u grave	ù	RA
250	FA	u acute	ú	RI
251	FB	u circumflex	û	RU
252	FC	u dieresis	ü	RE
253	FD	y acute	ý	RO
254	FE	thorn	Þ	WA
255	FF	y dieresis	ÿ	N

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